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(54) Title: USE OF ACRP30 GLOBULAR HEAD TO PROMOTE INCREASES IN MUSCLE MASS AND MUSCLE DIFFERENTIATION

(57) Abstract: The present invention relates to the field of muscle research, in particular to the discovery of a compound effective for increasing muscle mass, muscle cell differentiation, and oxidation of free fatty acids in muscle, useful in methods of treating muscle-related diseases and disorders as well as for augmenting muscle mass in general. The muscle-related diseases or disorders envisaged to be treated by the methods of the invention include, but are not limited to, muscular dystrophy, and other conditions resulting in muscle atrophy or muscle wasting.

USE OF ACRP30 GLOBULAR HEAD TO PROMOTE INCREASES IN MUSCLE MASS AND MUSCLE DIFFERENTIATION

FIELD OF THE INVENTION

The present invention relates to the field of muscle research, in particular to the discovery of a compound effective for increasing muscle mass, muscle cell differentiation, and oxidation of free fatty acids in muscle, that should be useful in methods of treating muscle-related diseases and disorders as well as for augmenting muscle mass. The muscle-related diseases or disorders envisaged to be treated by the methods of the invention include, but are not limited to, muscle-related eye diseases and disorders, muscle-related recovery after injuries, muscle-related recovery after surgery, muscle-related disorders of aging, muscular dystrophy, and other conditions resulting in muscle atrophy.

BACKGROUND OF THE INVENTION

Acrp30 (also known as AdipoQ) is the murine homolog of the human Apm1 protein (this class of proteins is generically referred to as OBG3 herein). The predicted protein structure of Apm1 indicates the presence of: 1) a secreted protein signal peptide, 2) a region containing collagen repeats, and 3) a globular region (Fig. 2), which is highly conserved (Fig.1).

Acrp30 is a circulating protein that is produced by the adipose tissue (WO 96/39429 which is hereby incorporated herein in its entirety including any figures, tables, or drawings). Acrp30 mRNA levels are significantly reduced in adipose tissue from obese *ob/ob* mice. Acrp30 expression is greatly increased during adipocyte differentiation and appears to be regulated by insulin. In addition, Acrp30 has been shown to reduce postprandial blood lipid levels, stimulate weight loss, and reduce plasma triglycerides in normal mice, and to promote the reduction of food intake in genetically obese mice (PCT Application No. 99/07736 which is hereby incorporated herein in its entirety including any figures, tables, or drawings).

Studies performed using just the globular region of Acrp30, termed globular Acrp30 (gAcrp30) showed that it effectively reduced body weight in mice on a high-fat cafeteria diet, as well as decreased fatty acid levels, decreased triglyceride levels, and improved glucose turnover in post-prandial tests in mice (See US Provisional Application No's 60/176,228 and 60/198,087, both of which are hereby incorporated herein by reference including any drawings, figures, or tables).

SUMMARY OF THE INVENTION

Globular OBG3 (gOBG3) has previously been linked with obesity, both in a murine model where treatment with gAcrp30 was shown to decrease body weight in mice fed a high fat diet, and in human subjects where an association between some Apm1 single nucleotide polymorphisms (SNPs)

and obesity was documented. The instant invention is drawn *inter alia* to the unexpected effects of gOBG3 on muscle cells, including increasing the oxidation of free fatty acid in muscle cells as well as accelerating muscle re-orientation/re-organization and differentiation.

In a first aspect, the invention features methods of accelerating muscle cell differentiation, comprising contacting muscle cells with gOBG3 thereby accelerating differentiation of the muscle cells. Preferably the contacting is performed under conditions such that gOBG3 binds to the muscle cells. Preferably the muscle cells are present in an individual. Preferably, gOBG3 is present in a pharmaceutical composition. The pharmaceutical composition preferably further comprises a pharmaceutically acceptable diluent. gOBG3 can be provided as a polypeptide or as a polynucleotide encoding gOBG3. Preferably, gOBG3 is gApm1.

In a second aspect, the invention features methods of accelerating muscle cell reorganization, comprising contacting muscle cells with gOBG3 thereby accelerating reorganization of the muscle cells. Preferably the muscle cells are present in an individual. Preferably the contacting is under conditions such that gOBG3 binds to the muscle cells. Preferably, gOBG3 is present in a pharmaceutical composition. The pharmaceutical composition preferably further comprises a pharmaceutically acceptable diluent. gOBG3 can be provided as a polypeptide or as a polynucleotide encoding gOBG3. Preferably, gOBG3 is gApm1.

In a third aspect, the invention features methods of accelerating muscle repair, comprising contacting muscle cells with gOBG3 thereby accelerating reorganization and differentiation of the muscle cells. Preferably the contacting is under conditions such that gOBG3 binds to the muscle cells. Preferably the muscle cells are present in an individual. Preferably, gOBG3 is present in a pharmaceutical composition. The pharmaceutical composition preferably further comprises a pharmaceutically acceptable diluent. gOBG3 can be provided as a polypeptide or as a polynucleotide encoding gOBG3. Preferably, gOBG3 is gApm1.

In a fourth aspect, the invention features methods of increasing muscle mass in an individual, comprising contacting muscle cells in the individual with gOBG3 thereby accelerating the reorganization and differentiation of the muscle cells and increasing the muscle mass of the individual. Preferably said contacting is under conditions wherein gOBG3 binds to muscle cells. Preferably, gOBG3 is present in a pharmaceutical composition. The pharmaceutical composition preferably further comprises a pharmaceutically acceptable diluent. gOBG3 can be provided as a polypeptide or as a polynucleotide encoding gOBG3. Preferably, gOBG3 is gApm1.

In a fifth aspect, the invention features methods of treating muscle cell disorders in an individual, comprising contacting muscle cells in the individual with gOBG3 thereby accelerating the reorganization and differentiation of the muscle cells, and thereby treating the muscle cell disorders. Preferably the contacting is under conditions wherein gOBG3 binds to muscle cells. In preferred embodiments, the muscle cell disorders are selected from the group consisting of muscle-

related eye diseases and disorders, muscle-related recovery after injuries, muscle-related recovery after surgery, muscle-related disorders of aging, muscle atrophy and muscular dystrophy. Preferably, gOBG3 is present in a pharmaceutical composition. The pharmaceutical composition preferably further comprises a pharmaceutically acceptable diluent. gOBG3 can be provided as a polypeptide or as a polynucleotide encoding gOBG3. Preferably, gOBG3 is gApm1.

Definitions

Before describing the invention in greater detail, the following definitions are set forth to illustrate and define the meaning and scope of the terms used to describe the invention herein.

As used herein, the term "OBG3" refers to any member of the family of homologous proteins that includes Apm1, the human homologue, as well as Acrp30 or AdipoQ, the mouse homologue. These proteins and the polynucleotides encoding them are described in detail in WO 96/39429 and US Patent applications 60/176,228 and 60/198,087, all of which are hereby incorporated by reference herein in their entirety including any drawings, figures, or tables.

The term "polypeptide" refers to a polymer of amino acids without regard to the length of the polymer. Thus, peptides, oligopeptides, and proteins are included within the definition of polypeptide. This term also does not specify or exclude post-expression modifications of polypeptides. For example, polypeptides which include the covalent attachment of glycosyl groups, acetyl groups, phosphate groups, lipid groups and the like are expressly encompassed by the term polypeptide. Also included within the definition are polypeptides which contain one or more analogs of an amino acid (including, for example, non-naturally occurring amino acids, amino acids which only occur naturally in an unrelated biological system, modified amino acids from mammalian systems etc.), polypeptides with substituted linkages, as well as other modifications known in the art, both naturally occurring and non-naturally occurring.

As used herein, the term "non-human animal" refers to any non-human vertebrate, birds and more usually mammals, preferably primates, farm animals such as swine, goats, sheep, donkeys, and horses, rabbits or rodents, more preferably rats or mice. As used herein, the term "animal" is used to refer to any vertebrate, preferably a mammal. Both the terms "animal" and "mammal" expressly embrace human subjects unless preceded with the term "non-human".

The term "individual" as used herein refers to a mammal, including animals, preferably mice, rats, dogs, cattle, sheep, or primates, most preferably humans that perceives a need (or for whom a need is perceived) to accelerate muscle cell differentiation, to accelerate muscle cell reorganization, or to increase muscle mass. "Perceives a need" does not necessarily refer to a clinical need, but may simply be the result of an aesthetic desire to increase muscle mass, or to facilitate athletic training. An individual can also be a "patient".

The term "patient" as used herein refers to a mammal, including animals, preferably mice, rats, dogs, cattle, sheep, or primates, most preferably humans that are in need of treatment. The term "in need of treatment" as used herein refers to a judgment made by a medical care-provider such as a physician, nurse practitioner, nurse or the like, that a patient could benefit from or requires treatment. This judgement is made based on a variety of factors that are in the realm of the medical care-provider's expertise, but that include the knowledge that the patient is ill, or will be ill, as the result of a condition that is treatable by the compounds of the invention.

The term "accelerating muscle cell differentiation" as used herein refers to the ability of compounds of the invention to decrease the number of hours muscle cell differentiation requires in the absence of the compound (or alternatively stated, to increase the process of differentiation). This decrease in hours is at least 5 hours, preferably at least 10 hours, more preferably at least 20 hours. Alternatively, accelerating muscle cell differentiation can refer to the ability of compounds of the invention to increase the numbers of muscle cells undergoing differentiation at a given time, compared to the number in the absence of the compound, or to decrease the amount of apoptosis of muscle cells compared with the amount of apoptosis at a given time in the absence of the compound. Muscle cell differentiation can be determined by visual inspection (Example 1) or through markers of muscle cell differentiation known in the art, some of which are described in Shimokawa et al (1998) (Biochem Biophys Res Commun 246:287-292; hereby incorporated herein by reference in its entirety including drawings, figures, and tables; Example 6).

The term "accelerating muscle cell reorganization" as used herein refers to the ability of compounds of the invention to increase muscle cell reorganization in the presence of the compound as compared to in its absence. Alternatively, accelerating muscle cell reorganization can refer to the ability of compounds of the invention to increase the numbers of muscle cells undergoing reorganization at a given time, compared to the number in the absence of the compound. Muscle cell reorganization can be determined by visual inspection (Example 1).

The term "increasing muscle mass" as used herein refers to the ability of compounds of the invention to increase the number of differentiated muscle cells as compared to the numbers in the absence of the compound. Muscle cell differentiation can be determined by visual inspection (Example 1) or through markers of muscle cell differentiation known in the art, some of which are described in Shimokawa et al (1998). Increases in muscle mass can also be determined by measurements of the overall size of a muscle or the strength of a muscle using techniques well-known in the art.

The term "muscle cell disorders" as used herein refers to disorders where there is a loss of muscle mass, or muscle strength. These would include muscle atrophy or muscle wasting as the result of disease or trauma, or malnutrition, for example. In addition, disorders such as muscle-related eye diseases and disorders, muscle-related recovery after injuries, muscle-related recovery after

surgery, muscle-related disorders of aging, and muscular dystrophy are specifically envisioned. Whereas some of these disorders would require a medical care provider's diagnosis (muscular dystrophy for example), others would simply require an individual to detect the change and desire the treatment (some forms of muscle wasting or muscle atrophy).

The terms "percentage of sequence identity" and "percentage homology" are used interchangeably herein to refer to comparisons among polynucleotides and polypeptides, and are determined by comparing two optimally aligned sequences over a comparison window, wherein the portion of the polynucleotide or polypeptide sequence in the comparison window may comprise additions or deletions (i.e., gaps) as compared to the reference sequence (which does not comprise additions or deletions) for optimal alignment of the two sequences. The percentage is calculated by determining the number of positions at which the identical nucleic acid base or amino acid residue occurs in both sequences to yield the number of matched positions, dividing the number of matched positions by the total number of positions in the window of comparison and multiplying the result by 100 to yield the percentage of sequence identity. Homology is evaluated using any of the variety of sequence comparison algorithms and programs known in the art. Such algorithms and programs include, but are by no means limited to, TBLASTN, BLASTP, FASTA, TFASTA, and CLUSTALW (Pearson and Lipman, 1988; Altschul et al., 1990; Thompson et al., 1994; Higgins et al., 1996; Altschul et al., 1990; Altschul et al., 1993). In a particularly preferred embodiment, protein and nucleic acid sequence homologies are evaluated using the Basic Local Alignment Search Tool ("BLAST") which is well known in the art (see, e.g., Karlin and Altschul, 1990; Altschul et al., 1990, 1993, 1997). In particular, five specific BLAST programs are used to perform the following task:

(1) BLASTP and BLAST3 compare an amino acid query sequence against a protein sequence database;

(2) BLASTN compares a nucleotide query sequence against a nucleotide sequence database;

(3) BLASTX compares the six-frame conceptual translation products of a query nucleotide sequence (both strands) against a protein sequence database;

(4) TBLASTN compares a query protein sequence against a nucleotide sequence database translated in all six reading frames (both strands); and

(5) TBLASTX compares the six-frame translations of a nucleotide query sequence against the six-frame translations of a nucleotide sequence database.

The BLAST programs identify homologous sequences by identifying similar segments, which are referred to herein as "high-scoring segment pairs," between a query amino or nucleic acid sequence and a test sequence which is preferably obtained from a protein or nucleic acid sequence database. High-scoring segment pairs are preferably identified (i.e., aligned) by means of a scoring

matrix, many of which are known in the art. Preferably, the scoring matrix used is the BLOSUM62 matrix (Gonnet et al., 1992; Henikoff and Henikoff, 1993). Less preferably, the PAM or PAM250 matrices may also be used (see, e.g., Schwartz and Dayhoff, eds., 1978). The BLAST programs evaluate the statistical significance of all high-scoring segment pairs identified, and preferably selects those segments which satisfy a user-specified threshold of significance, such as a user-specified percent homology. Preferably, the statistical significance of a high-scoring segment pair is evaluated using the statistical significance formula of Karlin (see, e.g., Karlin and Altschul, 1990).

By way of example and not limitation, procedures using conditions of high stringency are as follows: Prehybridization of filters containing DNA is carried out for 8 h to overnight at 65 °C in buffer composed of 6X SSC, 50 mM Tris-HCl (pH 7.5), 1 mM EDTA, 0.02% PVP, 0.02% Ficoll, 0.02% BSA, and 500 µg/mL denatured salmon sperm DNA. Filters are hybridized for 48 h at 65 °C, the preferred hybridization temperature, in prehybridization mixture containing 100 µg/mL denatured salmon sperm DNA and 5-20 X 10^6 cpm of ^{32}P-labeled probe. Alternatively, the hybridization step can be performed at 65 °C in the presence of SSC buffer, 1 x SSC corresponding to 0.15M NaCl and 0.05 M Na citrate. Subsequently, filter washes can be done at 37 °C for 1 h in a solution containing 2 x SSC, 0.01% PVP, 0.01% Ficoll, and 0.01% BSA, followed by a wash in 0.1 X SSC at 50 °C for 45 min. Alternatively, filter washes can be performed in a solution containing 2 x SSC and 0.1% SDS, or 0.5 x SSC and 0.1% SDS, or 0.1 x SSC and 0.1% SDS at 68 °C for 15 minute intervals. Following the wash steps, the hybridized probes are detectable by autoradiography. Other conditions of high stringency may also be used and are well known in the art (Sambrook et al., 1989 and Ausubel et al., 1989, both of which are hereby incorporated herein in their entirety including any drawings, figures, or tables). These hybridization conditions are suitable for a nucleic acid molecule of about 20 nucleotides in length. The hybridization conditions described can be adapted according to the length of the desired nucleic acid, following techniques well known to the one skilled in the art. The suitable hybridization conditions may, for example, be adapted according to Hames and Higgins (1985) or Sambrook et al. (1989).

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows an alignment of the sequences of the human (APM1), and mouse (adipoQ and acrp30) OBG3 proteins.

Figure 2 shows a schematic drawing of the protein structure of APM1. The putative signal sequence at the N-terminus (AA 1-15), the unique region (AA 16-42), the collagen region (AA 43-107), and the globular region (AA 108-244) at the carboxy terminus are shown. Two protease cleavage sites at AA 100 and AA 131 are also shown.

Figure 3 shows a graphical representation of the effect of the addition of gACRP30 on the oleate oxidation of differentiated C2C12 cells.

Figure 4 shows a graphical representation of the effect of gAcrp30 treatment on fatty acid metabolism in muscle isolated from mice. EDL and Soleus muscles were isolated from both legs of each mouse (n=18). One muscle of each pair was incubated in medium with 2.5 µg/mL gAcrp30 (dark gray) and one in medium without gAcrp30 (control – light gray).

Figures 5A and 5B show graphical representations of the effect of gAcrp30 treatment on triglyceride content of muscle and liver isolated from mice. Mice that had received 25 µg of gAcrp30 twice daily showed significantly higher (p=0.002) muscle triglyceride content (Fig.5A) than those receiving saline (control: light gray; gAcrp30: dark gray). This contrasted with a lack of increase in liver triglycerides (Fig. 5B).

Figures 6A and 6B show SDS-PAGE separations of the purification of Acrp30 and gAcrp30 (6A) and a cleavage product of apm1 (6B). Fig. 6A, Lane II shows the complete form of Acrp30 purified by FPLC. Lane I shows the proteolytic cleavage product gAcrp30. Fig. 6B shows a cleavage product of apm-1 after immunoprecipitation followed by Western blotting. The apparent molecular weight of this truncated form is 27kDa, corresponding to about 70% of the complete form of apm-1 (Lane IV). This truncated form was not detectable when a second anti-serum, specific for the human non-homologous region (HDQETTTQGPGVLLPLPKGA) of the protein was used for immunoprecipitation (Lane V) and the same anti-globular head antiserum for detection. A preimmune serum of the same animal did not detect any protein; a dimer of apm-1 was seen with both specific antibodies (apparent MW 74kDa).

DETAILED DESCRIPTION OF THE INVENTION

Globular OBG3 has previously been linked with obesity, both in a murine model where treatment with globular Acrp30 (gAcrp30) was shown to decrease body weight in mice fed a high fat diet, and in human subjects where an association between some Apm1 single nucleotide polymorphisms (SNPs) and obesity was documented. In the instant application, the inventors have shown *inter alia* that at least some of the effects of gOBG3 are directed toward muscle cells. These effects include increasing the oxidation of free fatty acid in muscle cells as well as accelerating muscle re-organization and differentiation. Although the oxidation of free fatty acid in muscle cells likely is linked to the weight loss previously observed, it also seems to be linked to the acceleration of muscle cell reorganization and differentiation.

The effect of gAcrp30 on muscle cells was assessed using the murine, skeletal muscle cell line C2C12, and in *ex vivo* experiments on muscle cells excised from mice. The C2C12 cells were originally isolated from normal C3H mouse thigh muscle 72 hours after the muscle was crushed to increase the yield of mononucleated myogenic cells and designated C2 cells (Yaffe & Saxel (1977) Nature 270:725-727). The C2C12 cell line is a sub-clone of the C2 cell line selected for its ability to differentiate rapidly and to produce extensive contracting myotubes expressing characteristic muscle

proteins (Blau et al (1985) Science 230:758-766). Thus, it appears that the C2C12 line is probably a clonal derivative of the satellite muscle cells present in muscle tissue that can replicate and differentiate to form additional muscle fibers.

Differentiation of C2C12 myocytes is induced when cultures are shifted to medium containing low concentrations of mitogens (Wang & Walsh (1996) Science 273:359-361). During this process myoblasts withdraw permanently from the cell cycle, express muscle specific structural proteins, and fuse into multinucleated myotubes (Davis et al (1987). Extensive cell death is also observed in cultures of C2C12 cells exposed to differentiation medium containing 2% horse serum beginning at 24 hours and reaching a maximum of 20-30% of cells at 48 hours (Wang & Walsh (1996)). After 72 to 96 hours myotubes become abundant and cell death is diminished.

The process of differentiation of the C2C12 cell line is a good model for studies for treatments of damaged muscle tissue following muscle injuries associated with strains and sprains, and tears normally encountered in daily life, as well as during intense athletic training, or as the result of accidental injury, or surgery. In all these instances, the muscle tissue is damaged, needs to re-orient/reorganize, and to grow new muscle fibers. Thus, treatments that enhance the reorientation/reorganization of the cultured muscle cells and their differentiation into muscle fibers should also be useful for accelerating the healing of muscle tissue following injury, as well as for accelerating the augmentation or strengthening of muscle cells during physical therapy, or athletic training.

Globular Acrp30 was found to induce pronounced re-orientation/re-organization of undifferentiated C2C12 muscle cells, as well as to accelerate the process of differentiation into muscle fibers. Further, there were indications of a decrease in apoptosis of muscle cells during the differentiation process, since the numbers of cells compared to the cells not treated with gOBG3 increased. Treatment of differentiated C2C12 cells with gAcrp30 also caused an increase in fatty acid metabolism, since oleate oxidation was increased approximately 40% (Fig. 3). A significant increase in oleate oxidation was also seen in *ex vivo* experiments with isolated mouse EDL and soleus muscles (Fig. 4), indicating the strength of the C2C12 cell line as a model system. A concurrent significant increase in triglyceride concentration was also observed in the *ex vivo* muscle.

Although not wishing to be limited to one hypothesis, the inventors believe that the increase in metabolism of free fatty acids that results from the addition of gAcrp30 may be involved in the acceleration of muscle cell reorientation/reorganization and differentiation. It is possible that the increase in fatty acid oxidation provides nutrients or energy that are involved in the process, or simply sends a signal. Whatever the exact mechanism involved, it is clear that treatment with gOBG3 has dramatic effects on muscle cells both *in vitro* and *in vivo*, for re-organization, differentiation and preventing apoptosis. Thus, it should be useful for treatment of muscle disorders where additional muscle tissue is desired and potentially where prevention of muscle cell death is

needed. Examples of such disorders include, but are not limited to, muscle wasting, muscle atrophy, or muscular dystrophy. Augmenting muscle differentiation and growth should be ameliorative to the symptoms, if not curative of the disease. Recruitment of more muscle cells, alignment, and differentiation of more muscle fibers should have a positive effect, and might at least prolong the useful life of the muscles of patients afflicted with muscular dystrophy.

PREFERRED EMBODIMENTS OF THE INVENTION

I. Muscle-related Uses of gOBG3

Methods of Accelerating Muscle Repair:

The inventors have shown that treatment of muscle cells with gOBG3 leads to their re-organization and differentiation, as well as increased free fatty acid oxidation, processes believed to be important in muscle repair. The muscle cell line used is one created as the result of trauma to skeletal muscle cells and is therefore thought to be a good model for studying muscle repair. Treatments that accelerate muscle cell re-organization, muscle cell differentiation, and/or muscle cell repair would be useful following any kind of muscle injury, including, but not limited to trauma, either accidental, or the result of surgery, or over-exercising. Trauma to muscles can result from blows, tears, cuts, strains, etc. gOBG3 variants and fragments, as well as agonists and antagonists of gOBG3, can be tested for their activity and thus their potential for use as treatments for the acceleration of muscle repair using the assays described in the Examples (particularly Examples 1, 2, 4, 6, 7) or in other assays known to those in the art.

Methods of Increasing Muscle Mass:

In addition to muscle repair, the results of treatment of muscle cells with gOBG3 suggest that gOBG3 treatment could also be useful for increasing muscle mass and/or increasing muscle strength and/or muscle endurance. Increasing body mass (for aesthetic or sports-related reasons, for example) also involves the recruitment and development of new muscle cells, which gAcrp30 has been shown to promote in the experiments with C2C12 cells. Further, increased free fatty acid oxidation should also be useful in any kind of endurance or other activities leading to muscle fatigue, since free fatty acids are a better source of energy and generally less easily utilized than glucose stores. To some extent, gOBG3 would be expected to function similarly to the anabolic steroid-type drugs currently used by athletes. gOBG3 variants and fragments, as well as agonists and antagonists of gOBG3, can be tested for their activity and thus their potential for use for increasing muscle mass, strength and/or endurance using the assays described in the Examples (particularly Examples 1, 2, 4, 6, 7) or assays known to those in the art.

Methods of Treatment of Muscle Disorders:

For similar reasons as those that suggest gOBG3 would be useful for accelerating muscle repair and increasing muscle mass, and additionally because it appears that gOBG3 may be useful in preventing apoptosis, gOBG3 should also be useful for treating muscle cell disorders. The muscle cell disorders contemplated are those that would improve, or whose symptoms would be ameliorated by treatment with gOBG3. These would include disorders in which the cells need to be strengthened (improve utilisation of free fatty acid), or the amount of muscle fibers increased (increased differentiation of muscle cells). For example, gOBG3 would be expected to be useful for treating the muscle cell disorders muscle atrophy, muscle wasting, and muscular dystrophy. Treatment with gOBG3 is expected to ameliorate some symptoms of these diseases by increasing the strength of the existing muscle cells by increasing their use of free fatty acids, and by increasing the differentiation of additional muscle cells, as well as by preventing the apoptosis of existing muscle cells. For instance, even though in muscular dystrophy the existing muscles are abnormal and their use is gradually lost, it is thought that gOBG3 should be able to increase the useful life of the muscles. gOBG3 variants and fragments, as well as agonists and antagonists of gOBG3, can be tested for their activity and thus their potential for use as treatments for muscle disorders using the assays described in the Examples (particularly Examples 1, 2, 4-8) or in other assays known to those in the art.

II. Globular OBG3 Polypeptides

Globular OBG3 polypeptides are used in the methods of treating muscle cells of the instant invention. As used herein, the term "gOBG3" refers to the globular portion of any member of the family of homologous proteins that includes Apm1, the human homologue, as well as Acrp30 or AdipoQ, the mouse homologue. Globular OBG3 polypeptides have previously been described in detail in US Provisional patent application Nos 60/176,228 and 60/198,087, hereby incorporated by reference herein in their entirety including figures, drawings, or tables. As used herein, unless specifically limited, the term is meant to include modified gOBG3 polypeptide sequences, including variants, fragments, analogs and derivatives of the gOBG3 polypeptides as described previously.

For the purposes of this invention, however, useful gOBG3 polypeptides are those that retain any one or more of the desired activities described herein, including but not limited to the effects on muscle cells that are the subject of the instant invention. These include accelerating re-orientation and differentiation of muscle cells as well as increasing free fatty acid oxidation, and preventing apoptosis. Variants, fragments, analogs and derivatives of these polypeptide sequences can be assayed for their retention of the desired activities using any of the methods/tests described in Examples 1,2, and 4-8 or any comparable assays.

Globular OBG3 is the portion of intact OBG3 that does not include the collagen-like tail, or that contains few enough of the collagen residues such that the peptides do not assemble, or if they assemble this does not inhibit their activity. Preferably, this is fewer than 6 collagen residues, fewer

than 4, fewer than 2, or more preferably no collagen residues. By "collagen residues" as used herein is meant the amino acids glycine, X, Y, where X and Y can be any amino acid. The collagen-like region of OBG3 is shown in Fig. 2 for APM1.

The term "activity" as used herein refers to a measurable result of the interaction of molecules. For example, a preferred gOBG3 activity is to accelerate re-orientation of muscle cells, accelerate differentiation of muscle cells, and/or increase free fatty acid oxidation of muscle cells. Representative assays to test for these functions are provided in Examples 1,2, and 4-9. However, these examples are provided for explanation, not limitation. Those with skill in the art would be able to design other experiments to test for the same retained activity.

The term the "same retained activity" as used herein refers to the ability of a variant, fragment, analog or derivative of gOBG3 to have the same activity as is demonstrated in Examples 1,2, and 4-8 and claimed in the instant invention. The variant, fragment, analog or derivative of gOBG3 does not necessarily have to retain all of the activities described herein for gOBG3's action on muscle cells, unless specified, but preferably retains at least one of the activities.

The "same activity" also relates to the amount of a given activity observed. In the instant application this refers to the amount of oleate oxidation, or amount of acceleration of differentiation, or amount of prevention of apoptosis, for example. Preferably, the "same" activity as it relates to amount, means within 10% of the previously observed amount, but it can include a difference of 20% or 30% or even 50%. However, this is not meant to limit the use of more effective gOBG3 polypeptides.

"More effective" gOBG3 polypeptides include those with an increased activity compared with the gAcrp30 polypeptide used in experiments described herein. The term "increased" as used herein refers to the ability of gOBG3 polypeptides to increase an activity in some measurable way as compared to an appropriate control. As a result of the presence of a gOBG3 variant, the levels of fatty acid oxidation, or muscle cell differentiation might increase, or the amount of apoptosis might decrease, for example, as compared to appropriate controls, typically the presence of gAcrp30 used in the experiments described herein. Preferably, an increase in activity is at least 25%, more preferably at least 50%, most preferably at least 100%.

"More effective" gOBG3 polypeptides may also include those that lack or have a decreased amount of one activity compared with the gAcrp30 polypeptide used in experiments described herein, and an increased amount of another activity compared with the gAcrp30 polypeptide used in experiments described herein. The term "decreased" as used herein refers to the ability of gOBG3 polypeptides to decrease an activity in some measurable way as compared to an appropriate control, such as the gAcrp30 polypeptide used in experiments described herein. As a result of the presence of a gOBG3 variant, fatty acid oxidation might decrease, for example, as compared to controls in the presence of the gAcrp30 polypeptide used in experiments described herein. Preferably, a decrease in

activity is at least 25%, more preferably at least 50%, most preferably at least 100%. The term "lack" as used herein refers to an inability to detect an activity using the methods described herein, or similar methods. A gOBG3 variant could be thought to "lack" activity even though an increase of 5 or 10 or 15% of an effect is observed compared with an assay performed in its absence.

Finally, "more effective" gOBG3 polypeptides may also include those that lack or have a decreased amount of one activity or all activities compared with the gAcrp30 polypeptide used in experiments described herein, but an increased amount of these activities *in vivo* as compared with the gAcrp30 polypeptide used in experiments described herein.

Preferred embodiments of the invention feature gOBG3 polypeptide that consists of the sequence of the globular region shown in Figure 1, or variants, fragments, analogs, or derivatives thereof. Preferable embodiments include amino acids 108-244 of SEQ ID NO:6 or 111-247 of SEQ ID Nos 2 and 4. Alternative preferable embodiments include amino acids 104 to 247 of the OBG3 proteins described in Figure 1.

In other preferred embodiments, the invention features a gOBG3 polypeptide comprising at least 115, but not more than 175 contiguous amino acids of any one of the gOBG3 polypeptide sequences set forth in Figure 1, wherein no more than 12 of said at least 115 and no more than 175 contiguous amino acids are present in the collagen-like region of OBG3. Preferably, the gOBG3 polypeptide comprises at least 125, but not more than 165, or at least 135, but not more than 155, and no more than 9 are in the collagen-like region; more preferably at least 125 but not more than 165, or 135 but not more than 155, and no more than 6 are in the collagen-like region; or at least 140 and not more than 150, and no more than 3 are present in the collagen-like region. Preferably the gOBG3 polypeptide is human or mouse, but most preferably human.

Variant gOBG3 polypeptides of the invention may be 1) ones in which one or more of the amino acid residues are substituted with a conserved or non-conserved amino acid residue and such substituted amino acid residue may or may not be one encoded by the genetic code, or 2) ones in which one or more of the amino acid residues includes a substituent group, or 3) ones in which a modified gOBG3 polypeptide is fused with another compound, such as a compound to increase the half-life of the polypeptide (for example, polyethylene glycol), or 4) ones in which the additional amino acids are fused to modify a gOBG3 polypeptide, such as a leader or secretory sequence or a sequence which is employed for purification of the modified gOBG3 polypeptide or a pre-protein sequence. Such variants are deemed to be within the scope of those skilled in the art. The retention of the desired activity (and thus desired gOBG3 polypeptides) can be determined using the assays described in Examples 1, 2, 4-8 or other assays that achieve the same result.

Amino acid changes present in a variant polypeptide may be non-conservative amino acid changes but more preferably are conservative amino acid changes. In cases where there are one or more amino acid changes, preferred gOBG3 polypeptides include those that retain the same

activities and activity levels as the reference gOBG3 polypeptide sequence, as well as those where the level of one or more activities is increased. Assays for determining gOBG3 polypeptide activities of the invention are described herein in the Examples (1, 2, 4-8) in more detail, but include accelerating muscle differentiation, muscle oleate oxidation, and decreasing muscle apoptosis, both *in vitro* and *in vivo*.

In preferred embodiments, the invention features a variant of a gOBG3 polypeptide that is at least 75% identical to gOBG3 polypeptide sequences selected from the group consisting of 101-244, 108-244, and 132-244 of SEQ ID NO:6, or 104-247, 111-247, and 135-247 of SEQ ID Nos 2 or 4. Preferably, the amino acid sequence is at least 85% identical, more preferably 90% identical, most preferably 95% identical and optionally 100% identical. Preferably the sequence is human or mouse, and most preferably human.

In yet other preferred embodiments, the invention features a variant of a gOBG3 polypeptide that comprises (or consists of) a 143 contiguous amino acid sequence, wherein at least 100 of the 143 amino acids are identical to amino acids 101-244 of SEQ ID NO:6 or 104-247 of SEQ ID Nos 2 or 4. Preferably, at least 113 of the 143 amino acids are identical, more preferably 127 of the 143 are identical, even more preferably 134 of the 143 are identical, and most preferably all of the amino acids are identical. Preferably the sequence is human or mouse, and most preferably human.

In yet other preferred embodiments, the invention features a variant of a gOBG3 polypeptide that comprises (or consists of) a 137 contiguous amino acid sequence, wherein at least 100 of the 137 amino acids are identical to amino acids 108-244 of SEQ ID NO:6 or 111-247 of SEQ ID Nos 2 or 4. Preferably, at least 113 of the 137 amino acids are identical, more preferably 127 of the 137 are identical, even more preferably 134 of the 137 are identical, and most preferably all of the amino acids are identical. Preferably the sequence is human or mouse, and most preferably human.

In yet other preferred embodiments, the invention features a variant of a gOBG3 polypeptide that comprises (or consists of) a 113 contiguous amino acid sequence, wherein at least 80 of the 113 amino acids are identical to amino acids 132-244 of SEQ ID NO:6 or 135-247 of SEQ ID Nos 2 or 4. Preferably, at least 90 of the 113 amino acids are identical, more preferably 100 of the 113 are identical, even more preferably 110 of the 113 are identical, and most preferably all of the amino acids are identical. Preferably the sequence is human or mouse, and most preferably human.

A polypeptide fragment is a polypeptide having a sequence that is entirely the same as part, but not all, of a given polypeptide sequence, preferably a gOBG3 polypeptide and variants thereof. Such fragments may be "free-standing", *i.e.* not part of or fused to other polypeptides, or they may be comprised within a single larger non-OBG3 polypeptide of which they form a part or region. However, several fragments may be comprised within a single larger polypeptide. As representative examples of gOBG3 polypeptide fragments of the invention, there may be mentioned those which have from about 5, 6, 7, 8, 9 or 10 to 15, 10 to 20, 15 to 40, 30 to 55, 40 to 70, 60 to 95, 80 to 130, or

90 to 144 amino acids long. Preferred are those fragments containing at least one amino acid substitution or deletion compared to a gOBG3 polypeptide.

III. Pharmaceutical Compositions

The gOBG3 polypeptides of the invention can be administered to a mammal, including a human patient, alone or in pharmaceutical compositions where they are mixed with suitable carriers or excipient(s). The pharmaceutical composition is then provided at a therapeutically or aesthetically effective dose. A therapeutically or aesthetically effective dose refers to that amount of gOBG3 sufficient to result in amelioration of symptoms of muscle-related disorders as determined by the methods described herein. A therapeutically or aesthetically effective dose can also refer to the amount of gOBG3 necessary for an increase in muscle mass or an increase in muscle strength or endurance in persons desiring this affect for aesthetic or athletic reasons alone. A therapeutically effective dosage of a gOBG3 polypeptide of the invention is that dosage that is adequate to promote muscle differentiation and/or increased free fatty acid oxidation, or decreased muscle cell apoptosis with continued or periodic use or administration. Techniques for formulation and administration of gOBG3 may be found in "Remington's Pharmaceutical Sciences," Mack Publishing Co., Easton, PA, latest edition.

Other diseases or disorders that gOBG3 could be used to treat or prevent include, but are not limited to, muscle atrophy, muscle wasting and muscular dystrophy.

Routes of Administration.

Suitable routes of administration include oral, rectal, transmucosal, or intestinal administration, parenteral delivery, including intramuscular, subcutaneous, intramedullary injections, as well as intrathecal, direct intraventricular, intravenous, intraperitoneal, intranasal or intraocular injections. A particularly useful method of administering compounds for promoting weight loss involves surgical implantation, for example into the abdominal cavity of the recipient, of a device for delivering gOBG3 over an extended period of time. Sustained release formulations of the invented medicaments particularly are contemplated.

Composition/Formulation

Pharmaceutical compositions and medicaments for use in accordance with the present invention may be formulated in a conventional manner using one or more physiologically acceptable carriers comprising excipients and auxiliaries. Proper formulation is dependent upon the route of administration chosen.

Certain of the medicaments described herein will include a pharmaceutically acceptable carrier and at least one polypeptide that is a gOBG3 polypeptide of the invention. For injection, the agents of

the invention may be formulated in aqueous solutions, preferably in physiologically compatible buffers such as Hanks's solution, Ringer's solution, or physiological saline buffer such as a phosphate or bicarbonate buffer. For transmucosal administration, penetrants appropriate to the barrier to be permeated are used in the formulation. Such penetrants are generally known in the art.

Pharmaceutical preparations that can be taken orally include push-fit capsules made of gelatin, as well as soft, sealed capsules made of gelatin and a plasticizer, such as glycerol or sorbitol. The push-fit capsules can contain the active ingredients in admixture with fillers such as lactose, binders such as starches, and/or lubricants such as talc or magnesium stearate and, optionally, stabilizers. In soft capsules, the active compounds may be dissolved or suspended in suitable liquids, such as fatty oils, liquid paraffin, or liquid polyethylene glycols. In addition, stabilizers may be added. All formulations for oral administration should be in dosages suitable for such administration.

For buccal administration, the compositions may take the form of tablets or lozenges formulated in conventional manner.

For administration by inhalation, the compounds for use according to the present invention are conveniently delivered in the form of an aerosol spray presentation from pressurized packs or a nebulizer, with the use of a suitable gaseous propellant, *e.g.,* carbon dioxide. In the case of a pressurized aerosol the dosage unit may be determined by providing a valve to deliver a metered amount. Capsules and cartridges of, *e.g.,* gelatin, for use in an inhaler or insufflator, may be formulated containing a powder mix of the compound and a suitable powder base such as lactose or starch.

The compounds may be formulated for parenteral administration by injection, *e.g.,* by bolus injection or continuous infusion. Formulations for injection may be presented in unit dosage form, *e.g.,* in ampoules or in multi-dose containers, with an added preservative. The compositions may take such forms as suspensions, solutions or emulsions in aqueous vehicles, and may contain formulatory agents such as suspending, stabilizing and/or dispersing agents.

Pharmaceutical formulations for parenteral administration include aqueous solutions of the active compounds in water-soluble form. Aqueous suspensions may contain substances that increase the viscosity of the suspension, such as sodium carboxymethyl cellulose, sorbitol, or dextran. Optionally, the suspension may also contain suitable stabilizers or agents that increase the solubility of the compounds to allow for the preparation of highly concentrated solutions.

Alternatively, the active ingredient may be in powder or lyophilized form for constitution with a suitable vehicle, such as sterile pyrogen-free water, before use.

In addition to the formulations described previously, the compounds may also be formulated as a depot preparation. Such long acting formulations may be administered by implantation (for example subcutaneously or intramuscularly) or by intramuscular injection. Thus, for example, the compounds may be formulated with suitable polymeric or hydrophobic materials (for example as an

emulsion in an acceptable oil) or ion exchange resins, or as sparingly soluble derivatives, for example, as a sparingly soluble salt.

Additionally, the compounds may be delivered using a sustained-release system, such as semipermeable matrices of solid hydrophobic polymers containing the therapeutic agent. Various sustained release materials have been established and are well known by those skilled in the art. Sustained-release capsules may, depending on their chemical nature, release the compounds for a few weeks up to over 100 days.

Depending on the chemical nature and the biological stability of the therapeutic reagent, additional strategies for protein stabilization may be employed.

The pharmaceutical compositions also may comprise suitable solid or gel phase carriers or excipients. Examples of such carriers or excipients include but are not limited to calcium carbonate, calcium phosphate, various sugars, starches, cellulose derivatives, gelatin, and polymers such as polyethylene glycols.

Effective Dosage.

Pharmaceutical compositions suitable for use in the present invention include compositions wherein the active ingredients are contained in an effective amount to achieve their intended purpose. More specifically, a therapeutically effective amount means an amount effective to prevent development of or to alleviate the existing symptoms of the subject being treated. Determination of the effective amounts is well within the capability of those skilled in the art, especially in light of the detailed disclosure provided herein.

For any compound used in the method of the invention, the therapeutically effective dose can be estimated initially from cell culture assays. For example, a dose can be formulated in animal models to achieve a circulating concentration range that includes or encompasses a concentration point or range shown to increase leptin or lipoprotein uptake or binding in an *in vitro* system. Such information can be used to more accurately determine useful doses in humans.

A therapeutically effective dose refers to that amount of the compound that results in amelioration of symptoms in a patient. Toxicity and therapeutic efficacy of such compounds can be determined by standard pharmaceutical procedures in cell cultures or experimental animals, *e.g.*, for determining the LD50, (the dose lethal to 50% of the test population) and the ED50 (the dose therapeutically effective in 50% of the population). The dose ratio between toxic and therapeutic effects is the therapeutic index and it can be expressed as the ratio between LD5O and ED5O. Compounds that exhibit high therapeutic indices are preferred.

The data obtained from these cell culture assays and animal studies can be used in formulating a range of dosage for use in human. The dosage of such compounds lies preferably within a range of circulating concentrations that include the ED50, with little or no toxicity. The dosage may vary

within this range depending upon the dosage form employed and the route of administration utilized. The exact formulation, route of administration and dosage can be chosen by the individual physician in view of the patient's condition. *(See, e.g.,* Fingl et al., 1975, in "The Pharmacological Basis of Therapeutics", Ch. 1).

Dosage amount and interval may be adjusted individually to provide plasma levels of the active compound which are sufficient to maintain the weight loss or prevention of weight gain effects. Dosages necessary to achieve these effects will depend on individual characteristics and route of administration.

Dosage intervals can also be determined using the value for the minimum effective concentration. Compounds should be administered using a regimen that maintains plasma levels above the minimum effective concentration for 10-90% of the time, preferably between 30-90%; and most preferably between 50-90%. In cases of local administration or selective uptake, the effective local concentration of the drug may not be related to plasma concentration.

The amount of composition administered will, of course, be dependent on the subject being treated, on the subject's weight, the severity of the affliction, the manner of administration and the judgment of the prescribing physician.

A preferred dosage range for the amount of a gOBG3 polypeptide of the invention, that can be administered on a daily or regular basis to achieve desired results, including a reduction in levels of circulating plasma triglyceride-rich lipoproteins, range from 0.01 - 50 mg/kg body mass. A more preferred dosage range is from 0.02 - 25 mg/kg. A still more preferred dosage range is from 0.1 - 20 mg/kg, while the most preferred range is from 0.2 - 10 mg/kg. Of course, these daily dosages can be delivered or administered in small amounts periodically during the course of a day.

EXAMPLES

Other characteristics and advantages of the invention are described in the Examples. The following Examples are provided for illustrative purposes and not as a means of limitation. One of ordinary skill in the art would be able to design equivalent assays and methods based on the disclosure herein, all of which form part of the instant invention.

Throughout this application, various publications, patents and published patent applications are cited. The disclosures of these publications, patents and published patent specifications referenced in this application are hereby incorporated by reference into the present disclosure.

EXAMPLE 1: Effect of gACRP30 Treatment of Muscle Cells on Muscle Differentiation

C2C12 cells (murine skeletal muscle cell line; ATCC CRL 1772, Rockville, MD) are seeded sparsely (about 15-20%) in complete DMEM (w/glutamine, pen/strep, etc) + 10% FCS. Two days later they become 80-90% confluent. At this time, the media is changed to DMEM+2% horse serum

to allow differentiation. The media is changed daily. Abundant myotube formation occurs after 3-4 days of being in 2% horse serum.

To test the effect of the presence of gACRP30 on muscle differentiation, gACRP30 (1 to 2 µg/mL) was added the day after seeding when the cells are still in DMEM w/ 10% FCS. Two days after plating the cells (one day after gACRP30 was first added), at about 80-90% confluency, the media was changed to DMEM+2% horse serum plus gACRP30.

The results show that the addition of gACRP30 causes the cells to begin organizing within one day after its addition. In contrast to the random orientation of the cells not treated with gACRP30, those treated with gARCP30 aligned themselves in relation to each other. In addition, differentiation progressed more rapidly in the presence o gAcrp30; after only 2 days of gACRP30 treatment maximal or near maximal differentiation was observed in contrast to the 3 to 4 days needed in its absence.

EXAMPLE 2: Effect of gAcrp30 on Muscle Cell Fatty Acid Oxidation

C2C12 cells were differentiated in the presence or absence of 2 µg/mL gACRP30 for 4 days. On day 4, oleate oxidation rates were determined by measuring conversion of 1-^{14}C-oleate (0.2 mM) to $^{14}CO_2$ for 90 min. C2C12 cells differentiated in the presence of gACRP30 undergo 40% more oleate oxidation than controls differentiated in the absence of oleate (Fig. 3).

The effect of gAcrp30 on the rate of oleate oxidation was compared in differentiated C2C12 cells (murine skeletal muscle cells; ATCC, Manassas, VA CRL-1772) and in a hepatocyte cell line (Hepa1-6; ATCC, Manassas, VA CRL-1830). Cultured cells were maintained according to manufacturer's instructions.

The oleate oxidation assay was performed as previously described (Muoio et al (1999) Biochem J 338:783-791). Briefly, nearly confluent myocytes were kept in low serum differentiation media (DMEM, 2.5% Horse serum) for 4 days, at which time formation of myotubes became maximal. Hepatocytes were kept in the same DMEM medium supplemented with 10% FCS for 2 days. One hour prior to the experiment the media was removed and 1 mL of preincubation media (MEM, 2.5% Horse serum, 3 mM glucose, 4 mM Glutamine, 25 mM Hepes, 1% FFA free BSA, 0.25 mM Oleate, 5 µg/mL gentamycin) was added. At the start of the oxidation experiment, ^{14}C-Oleic acid (1µCi/mL, American Radiolabeled Chemical Inc., St. Louis, MO) was added and cells were incubated for 90 min at 37 °C in the absence/presence of 2.5 µg/mL gAcrp30. After the incubation period, 0.75 mL of the media was removed and was assayed for ^{14}C-oxidation products as described for the muscle FFA oxidation experiment.

Oleate oxidation in C2C12 cells determined over 90 min increased significantly (39%; $p = 0.036$, two-tailed t-Test) in cells treated with gAcrp30. In contrast, no detectable increase in the rate of FFA oxidation was seen in hepatocytes incubated with gAcrp30.

Triglyceride and Protein Analysis following Oleate Oxidation in cultured cells

Following the transfer of media for the oleate oxidation assay, cells were placed on ice. To determine triglyceride and protein content, cells were washed with 1 mL of 1x PBS to remove residual media. To each well, 300 µL of cell dissociation solution (Sigma) was added. Cells were incubated at 37 °C for 10 min. Plates were tapped to loosen cells, and 0.5 mL of 1x PBS was added. The cell suspension was transferred to an eppendorf tube, each well was rinsed with an additional 0.5 mL of 1x PBS, and the rinse was transferred to appropriate eppendorf tube. Samples were centrifuged at 1000 rpm for 10 minutes at room temperature. The supernatant was discarded, and 750 µL of 1x PBS/2% chaps was added to each cell pellet. The cell suspension was vortexed and was placed on ice for 1 hour. Samples were then centrifuged at 13000 rpm for 20 min at 4 °C. Supernatants were transferred to new tubes and frozen at –20 °C until analyzed.

The amount of triglycerides in each sample was determined using Sigma Diagnostics GPO-TRINDER enzymatic kit. The procedure outlined in the manual was adhered to with the following exceptions: the assay was performed in a 48 well plate, 350 µL of sample volume was assayed, the control blank consisted of 350 µL PBS/2% chaps, and the standard contained 10 µL of the standard provided in the kit plus 690 µL PBS/2% chaps. Analysis of the samples was performed on a Packard Spectra Count at a wavelength of 550 nm.

Protein analysis was carried out on 25 µL of each supernatant sample using the BCA protein assay (Pierce) following manufacturer's instructions. Analysis of the samples was performed on a Packard Spectra Count at a wavelength of 550 nm.

Triglyceride production in both C2C12 and Hepa 1-6 cells did not change significantly in the absence/presence of Acrp30 and gAcrp30. The protein content of all cells analyzed was equivalent in the absence/presence of Acrp30 and gAcrp30.

EXAMPLE 3: Production of Recombinant Acrp30

An illustrative method for producing recombinant OBG3 is given below. Although the method describes the production of the mouse analog, Acrp30, a person of ordinary skill in the art would be able to use the guidance provided to produce other OBG3 analogs, including but not limited to, the human analog, Apm1.

Recombinant Acrp30 is cloned in pTRC His B (Invitrogen) between BamH1 and Xho1 and maintained in *E. coli* DH5-α. The sequence of the Acrp30 insert corresponds to Acrp 30 genbank U37222 bases 88 to 791, except in position 382 where in #3 G replaces A found in ACRP 30 (V instead of M). The corresponding nucleotide in AdipoQ U49915 is G as in clone #3. The amino acid V is also conserved in the human sequence Apm-1 D45371.

Culture:

Plate out bacteria in LB agar media containing 100 µg/mL ampicillin. Inoculate 1 colony into 5 mL media (no agar) at 37 °C overnight. Add 2 mL of this initial culture into 500 mL Erlenmeyer flasks containing 200 mL LB media and 100 µg/mL ampicillin. Incubate at 37 °C in an orbital shaker until the OD_{600} = 0.2. Add IPTG to a final concentration of 1 mM (stock solution = 1 M). Incubate at 37 °C overnight.

Lysis:

Pellet the bacteria by centrifugation (Sorvall, 3500 rpm, 15 min, 4 °C) in a pre-weighed tube.
At 4 °C resuspend the pellet in 3 mL/g of lysis buffer
Add 40 µL/g PMSF 10 mM
Add 80 µL/g of lysozyme 10 mg/mL
Incubate 20 min on ice, shaking intermittently
Add 30 µL/g 10 % sodium deoxycholate
Incubate at 37 °C until the lysate is viscous
Freeze in liquid Nitrogen and thaw at 37 °C three times
Sonicate 2X, 30 sec, 25 % cycle, 2.5 power level
Centrifuge 30 min, 15000 rpm, 4 °C
Recover the supernatant
Note: The lysate can be stored frozen before or after the sonication step.

Batch Purification:

1. Pack 1 mL of Probond resin (Invitrogen; 1 mL= 2 mL suspended gel) into a 5 mL column. Wash with 5 mL PBS.
2. Apply 5 mL bacterial supernatant to the 1 mL of gel. (If volume is very high, use several small columns.)
3. Wash with 24 mL phosphate buffer, pH 7.8, followed by a wash with 24 mL phosphate buffer, pH 6.
4. Elute with imidazole buffer and collect fractions of 1 mL.
5. Analyze fractions by OD at 280 nm or by SDS-PAGE (12.5 %; dilution ½ in 2X sample buffer) under reducing conditions (100 °C, 5 min)
6. Pool the fractions containing protein (usually fraction numbers 2-4 for concentrations of 0.8 – 1 mg/mL and fractions 1, 5 and 6 for concentrations of 0.2 – 0.4 mg/mL).
7. Dialyze thoroughly against 1 X PBS, 24 mM ammonium bicarbonate or 50 mM Tris, pH 7.4 containing 250 nM NaCl. Concentrate by Speed-Vac if needed.
8. Analyze protein by the Lowry method.

9. Aliquot and store at –20 °C.

Purification On Liquid Chromatography System

1. Pack 5 mL of Probond resin into a 5 mL column.
2. Wash with 4 bed volumes of phosphate buffer pH 7.8, 1 mL/min.
3. Inject 25 mL lysate (filtered on 0.45 μ or centrifuged at 3000 rpm, 30 min, 4 °C, Beckman Allegra 6R) at 0.5 mL/min.
4. Wash with 4 bed volumes of phosphate buffer, pH 7.8 at 1 mL/min.
5. Wash with 12 bed volumes of phosphate buffer pH 5.5 at 1 mL/min.
6. Elute bound fraction with phosphate buffer, pH 5.5, containing 1 M imidazole at 1 mL/min.
7. Collect fractions, dialyze and analyze protein as described for batch purification, steps 7-9.

EXAMPLE 4: Generation of Globular Acrp30 by Enzymatic Cleavage

Incubate purified Acrp30 (obtained as described above or through equivalent method) with acetylated Trypsin-Type V-S from Bovine Pancreas (Sigma E.C. = 3.4.21.4) at 400 u/mg protein at 25 °C for 10 min.

Stop reaction by running the sample over a Poly-Prep Column (Biorad 731-1550) at + 4 °C containing immobilized Trypsin inhibitor.

Collect 1.0 mL fractions. Determine protein concentration.

Pool the protein containing fractions and dialyze extensively against PBS using dialysis tubing with M.W. cutoff = 10,000 da.

Concentrate on Amicon YM-10 Centricon Filter (Millipore, M.W. cutoff = 10,000 da). Sterile filter.

Determine final protein concentration using Markwell's modified Lowry procedure (1981) or BCA protein assay (Pierce Chemical Co, Rockford, IL) and BSA as standard.

Check purity and efficiency of cleavage by SDS – PAGE analysis using a 4-20% gradient gel. The intact Acrp30 migrates as a single band at approx. 37 kda due to co-transcribed vector sequences attached to the histidine tag at the N-terminus of Acrp30. The cleaved Acrp30 forms a band at approx. 18 kda (gAcrp30). Additional degradation products, all smaller than 10 kda are also generated from the N-terminal region. These are separated from the desired 18 kda band by dialysis with semipermeable membranes with a MW cutoff of 10,000. The actual cleavage site using this method has been identified as the one after amino acid 103.

Example 4: Effect of ACRP30 on Oleate Oxidation in Isolated Muscle

Intact muscles were isolated from C57BL6/J mice and the oleate oxidation of the isolated muscle was measured (Clee et al (2000) J Lipid Res 41:521-531; Muoio et al (1999) Am J Physiol 276:E913-921). Oleate oxidation in isolated muscle was measured as previously described (Cuendet et al (1976) J Clin Invest 58:1078-1088; Le Marchand-Brustel (1978) Am J Physiol 234:E348-E358, hereby incorporated by reference herein in its entirety including any figures, drawings, or tables).

Two groups of C57BL6/J mice, age 5 and 33 weeks, were used. Mice were kept on a regular diet with free access to food and water. The day/night light cycle was kept at 12hr ON/12hr OFF. The older animals were injected twice daily with either saline or 25 μg of gACRP30 for 3-4 days. The younger group of animals was given a high fat meal (6g butter, 6g sunflower oil, 10 g nonfat dry milk, 10 g sucrose, 12 mL distilled water prepared fresh) by gavage (vol.=1% of body weight) at time 0 and was injected with saline or gACRP30 only at time 0 and again at 45 minutes. They were sacrificed at 180 minutes. The gACRP30 used was prepared as described in Example 3.

After cervical dislocation, soleus and EDL muscles were rapidly isolated from the hind limbs of the mice. The distal tendon of each muscle was tied to a piece of suture to facilitate transfer among different media. All incubations were carried out at 30 °C in 1.5 mL of Krebs-Ringer bicarbonate buffer (118.6 mM NaCl, 4.76 mM KCl, 1.19 mM KH_2PO_4, 1.19 mM $MgSO_4$, 2.54 mM $CaCl_2$, 10 mM Hepes, pH 7.4) supplemented with 4% bovine serum albumin, FFA free (fraction V, RIA grade, Sigma, Inc., St. Louis, MO) and 5 mM glucose (Sigma, Inc., St. Louis, MO). The concentration of oleate (Sigma, Inc., St. Louis, MO) throughout the experiment was 0.25 mM. All media were oxygenated (95% O_2; 5% CO_2) prior to incubation. The gas mixture was hydrated throughout the experiment by bubbling through a gas washer (Kontes Inc., Vineland, NJ).

Muscles were rinsed for 30 min in incubation media with oxygenation. The muscles were then transferred to fresh media (1.5 mL) and incubated at 30 °C in the presence of 1 μCi/mL [1-^{14}C] oleic acid (ARC) and 1 μCi/mL [5-^{3}H]-glucose (Amersham). The incubation vials containing this media were sealed with a rubber septum from which a center well carrying a piece of Whatman paper (1.5 cm x 11.5 cm) was suspended.

After an initial incubation period of 10 min with constant oxygenation, gas circulation was removed to close the system to the outside environment. The muscles were incubated for an additional 90 min at 30 °C. At the end of this period, 0.45 mL of Solvable (Packard Instruments, Meriden, CT) was injected onto the Whatman paper in the center well. The oxidation of oleate by the muscle was stopped at this time point by transferring the vial onto ice.

After 5 min, the muscle was removed from the medium, was cleaned of connective tissue, was weighed and was frozen for further analysis. An aliquot of 0.5 mL medium was removed, the vials were closed again and 1 mL of 35% perchloric acid was injected with a syringe into the media by piercing through the rubber septum with a needle. The CO_2 released from the acidified media was collected by the Solvable in the center well.

After a 90 min collection period at 30 °C, the Whatman paper was removed from the center well and placed in scintillation vials containing 15 mL of scintillation fluid (HionicFlour, Packard Instruments, Meriden, CT). The amount of ^{14}C radioactivity was quantitated by liquid scintillation counting. The rate of oleate oxidation was expressed as nmol oleate produced in 90 min/g muscle.

To test the effect of gACRP30 or ACRP30 on oleate oxidation, these proteins were added to the media at a final concentration of 2.5 µg/mL and maintained in the media throughout the procedure. Two muscles of different oxidative capacity (soleus and extensor digitorum longus (EDL)) were tested (Fig. 4). EDL and Soleus muscles were isolated from both legs of normal C57BL/6J mice (n=18). One muscle of each pair was incubated in medium with 2.5 µg/mL gAcrp30 (dark gray) and one in medium without gAcrp30 (control – light gray). This experimental design allowed us to compare oleate oxidation in pairs of muscles isolated from the same animal. ^{14}C-Oleate oxidation was determined over 90 minutes. Incubation of EDL and soleus muscles for 90 minutes in medium containing 2.5µg/ml gAcrp30 leads to a statistically significant increase in oleate oxidation ($p<0.05$, paired, one-tailed, t-Test) or ($p=0.0041$, Repeated Measures Analysis of Variance, Univariate Tests of Hypotheses for Within Subject Effects) in both muscle types.

Both muscle types showed a significant response to gAcrp30. The relative increase in FFA oxidation was 17% ($p=0.03$) and 10% ($p=0.04$) for EDL and soleus, respectively. In humans, muscles represent approximately 25% of body weight. Therefore, even a moderate increase in free fatty acid oxidation can have quantitatively important consequences on overall energy utilization.

In summary, these experiments show that gAcrp30 acts on muscle cells *in vivo* and *ex vivo*. The invention is drawn, *inter alia,* to the effects of gAcrp30 on muscle resulting in increased lean muscle mass and exercise capability. The increase in oleate oxidation seen in these whole muscle experiments, suggests that experiments done using the simpler C2C12 cell line model are predictive for effects *in vivo*.

The hindlimb muscle and liver triglyceride content was measured after gAcrp30 treatment of mice. Hind limb muscles as well as liver samples were removed from treated and untreated animals and the triglyceride and free fatty acid concentration was determined following a standard lipid extraction method (Shimabukuro et al (1997) Proc Natl Acad Sci USA 94:4637-4641, hereby incorporated herein by reference in its entirety including any figures, drawings, or tables) followed by TG and FFA analysis using standard test kits.

Short-term treatment of animals with gAcrp30 (2 injections of 25 µg each given within 3 hours before sacrifice) did not change the triglyceride content either of hind limb muscle or liver tissue. However, after 3 days of treatment, during which period normal C57BL/6J mice consumed a regular rodent diet, mice that had received 25 µg of gAcrp30 twice daily showed significantly higher ($p=0.002$) muscle triglyceride content (Fig.5A) than those receiving saline (control: light gray; gAcrp30: dark gray). This contrasted with a lack of increase in liver triglycerides (Fig. 5B).

Furthermore, no detectable increase in muscle TG was observed after the 16-day treatment shown independently by directly measuring the muscle TG content and by oil red O staining of frozen microscope sections. In summary, the data indicate that the increase in TG content was transient.

Ketone bodies (KB) are produced in the liver as a result of free fatty acid oxidation, but KB formation does not occur significantly in muscle. In mice receiving the high fat test meal and saline injection, the level of plasma KB increased significantly over the next 3 hours (183 ± 12%, n=6). Animals treated with gAcrp30, on the other hand, showed no increase in plasma KB concentrations. Although not wishing to be limited by any particular theory, this suggests that gAcrp30 inhibits either directly KB formation or can decrease KB production by inhibiting liver FFA oxidation.

Example 5: Methods of Testing the Effect of gOBG3 on Apoptosis

Prior experiments indicated that gAcrp30 either increased cell division or decreased apoptosis is C2C12 cells undergoing differentiation (Example 1). In order to assess the effect C2C12 cells can be transferred into medium containing 0.5% horse serum (rather than 2% horse serum for differentiation), which rapidly induces the onset of apoptosis (Wang & Walsh (1996) hereby incorporated herein by reference in its entirety including any figures, tables, or drawings). Cells would then be incubated for 16 hours either in the presence or absence of gACRP30 and then the level of apoptosis compared by staining for ApopTag as described in Wang & Walsh(1996).

Example 6: Methods of Assessing the Acceleration of Myoblast Differentiation with gOBG3

Prior experiments have also indicated that gAcrp30 accelerates re-organization/reorientation and differentiation of C2C12 muscle cells *in vitro* (Example 1). Rapid, highly sensitive methods are available to facilitate screening of the activity of variants of gAcrp30 (and antagonists and agonists) for their effect on differentiation. These assays include, among others, a TaqMan PCR-based method that assesses mRNA levels of muscle-specific markers of differentiation, inlcuding, but not limited to, muscle regulatory factor, myogen, alpha-actin, thermoregulatory uncoupling protein (UCP2), glucose transporter isotype glut4, myf5, beta-actin, UCP1, UCP3, and glut1 (Shimokawa et al (1998) Biochem Biophys Res Commun 246:287-292, hereby incorporated by reference herein in its entirety including any figures, drawings, or tables). Levels of mRNA would be compared between the gAcrp30 treated and the untreated cultures of differentiating C2C12 cells.

Example 7: Effect of gOBG3 on Muscle Cells *in vivo*

Experiments can be performed on normal mice as well as mice fed a high fat diet, to assess increases in the differentiation of muscle cells over a time course of treatment using the TaqMan PCR-based method described in Example 6, for example. Other muscle cell parameters discussed

herein can also be assessed over time. The animal experiments can be performed as follows, for example:

Experiment 1: 10-week-old male C57BL/6J mice were put on a very high fat/sucrose purified diet for 19 days to promote weight gain (see Example 4); the average body weight at this time was 30g. The mice were then surgically implanted with an osmotic pump (Alzet, Newark, DE) delivering either 2.5 µg/day of gAcrp30, 5µg/day of Acrp30, or physiological saline. The mice were continued on the high fat diet and their body weight was recorded over the following 10-day period. Muscle parameters can be assessed over this same time period.

Experiment 2: mature 9 month old, male obese C57BL/6J mice that had been on the same high fat/sucrose diet for 6 months; the average body weight when the study began was 52.5±0.8g. Three groups of 8 mice were treated with saline, Acrp30 or gAcrp30 for 16 days. Animals in the treated group received twice daily 25 µg of protein subcutaneously. Body weights were recorded at appropriate time points (daily or weekly). Muscle parameters can also be assessed over the same time period.

Example 8: Mouse Models of Muscular Dystrophy

In order to further assess the efficacy of gAcrp30 and analogs, variants, and fragments thereof (as well as antagonists or agonists as needed) mouse models of muscular dystrophy can be used including, but not limited to, 129P1/ReJ-*Lama2*^{dy}, C57BL/10ScSn-*Dmd*^{mdx}/J, C57BL/6J-*Lama2*^{dy}, C57BL/6J- *Lama2*$^{dy\text{-}2J}$, C57BL/6Ros-*Dmd*$^{mdx\text{-}2Cv}$, C57BL/6Ros-*Dmd*$^{mdx\text{-}3Cv}$, C57BL/6Ros-*Dmd*$^{mdx\text{-}4Cv}$, C57BL/6Ros-*Dmd*^{mdx52Cv}, and D.B/20Ei-*Lama2*$^{dy\text{-}6J}$/+, all of which are available from Jackson Laboratories. The experiments would include beginning to treat mice as young as possible (and then starting at increasingly later time points) with gAcrp30 as described in Example 7 and comparing the onset and severity of disease symptoms with untreated mice.

Example 9:Cellular Binding and Uptake of gOBG-3 as Detected by Fluorescence Microscopy

Fluorecein isothiocyanate (FITC) conjugation of gOBG3: Purified gOBG3 at 1 mg/mL concentration was labeled with FITC using Sigma's FluoroTag FITC conjugation kit (Stock No. FITC-1). Protocol outlined in the Sigma Handbook for small scale conjugation was followed for gOBG3 labeling.

Cell Culture: C2C12 mouse skeletal muscle cells (ATCC, Manassas, VA CRL-1772) and Hepa-1-6 mouse hepatocytes (ATCC, Manassas, VA CRL-1830) were seeded into 6 well plates at a cell density of $2x10^5$ cells per well. C2C12 and Hepa-1-6 cells were cultured according to repository's instructions for 24-48 hours prior to analysis. Assay was performed when cells were 80% confluent.

FITC labeled gOBG3 cellular binding and uptake using microscopy in C2C12 and Hepa 1-6 cells. FITC- gOBG3 (50 nM/mL) was added to each cell culture well. Cells were incubated for 1

hour at 37 °C, 5% CO_2. Cells were washed 2x with PBS, cells were scraped from well into 1 mL of PBS. Cell suspension was transferred to an eppendorf tube and centrifuged at 1000 rpm for 2 minutes. Supernatant was removed and cells resuspended in 200 µL of PBS. Binding and uptake of FITC- gOBG3 was analyzed by fluorescence microscopy under 40X magnification.

Analysis of C2C12 and Hepa 1-6 cells reveals identical phenotypes with respect to FITC-gOBG3 binding and uptake profiles. FITC- gOBG3 appears to be localized within vesicles in the cytoplasm of both mouse hepatocytes and mouse myoblasts, suggesting that binding and uptake of FITC-gOBG3 is occurring. Thus, this assay may be useful for identifying agents that facilitate or prevent the uptake and/or binding of OBG3 or gOBG3 polypeptides to cells by adding the substance to be tested with, before, or after the FITC-gOBG3.

EXAMPLE 10: Detection of Apm-1 Fragment in Human Plasma after Immunoprecipitation

The recombinant form of Acrp30 protein used has an apparent molecular weight of 37 kDa and forms a dimer of 74 kDa (Fig 6 A, Lane II). A proteolytic fragment that contains the entire globular head region (gAcrp30) and that migrates with an apparent molecular weight of 18 kDa was generated using acetylated trypsin (Fig. 6A, lane I). Both protein preparations (Acrp30 and gAcrp30) were essentially endotoxin free; "ActiClean Etox" affinity columns were used to remove potential endotoxin contaminations (Sterogene Bioseparations Inc., Carlsbad, CA) following the manufacturer's protocol. Endotoxin levels were determined by Endosafe, Charleston, SC. As determined by N-terminal sequencing of purified gAcrp30, the site of cleavage was just before amino acid 104.

Immunoprecipitation of human plasma Apm1 followed by Western blotting was used to detect a cleavage product of Apm-1, the human homolog of Acrp30, using a globular head specific anti-serum for the immunoprecipitation step as well as for the detection step. Preimmune serum or serum raised against the globular head domain or human non-homologous region (HDQETTTQGPGVLLPLPKGA) were cross-linked to protein A (Sigma Chemical CO, Saint Louis, MO) using dimethyl-pimelimidate-dihydrochloride (Sigma Chemical Co, Saint Louis, MO). After washing (0.2 M salt), proteins were eluted from protein A, were separated by SDS-PAGE, and were transferred to Protran® pure nitrocellulose membrane (Schleicher and Schuell, Keene, NH) using standard procedures. Apm-1 products were visualized using globular head domain antibodies labeled with biotin; horseradish peroxidase conjugated to Streptavidin and CN/DAB substrate kit (Pierce, Rockford, IL) according to manufacturer's instructions.

The apparent molecular weight of this truncated form was 27 kDa, corresponding to about 70% of the complete form of Apm-1 (Fig. 6B, Lane IV). This truncated form was not detectable when immunoprecipitation was performed using a different antibody directed against the human non-homologous region (HDQETTTQGPGVLLPLPKGA) of Apm-1; this domain is located toward

the NH_2 terminal end of the protein outside of the globular domain (Fig. 6, Lane V). Both anti-Apm-1 antibodies directed against either the globular or the non-globular domain identified the full-length form of the protein, as well as a low abundance dimer of apparent MW 74 kDa.

EXAMPLE 11: Tissue Distribution of gAcrp30

Intra venous Injection of ^{125}I (g)Acrp30

The disappearance from plasma and subsequent tissue distribution of Acrp30 and the globular head (gAcrp30) was investigated by injecting ^{125}I (g)Acrp30 into CD-1 mice.

CD-1 mice were kept on regular diet with free access to food and water. The day/night light cycle was kept at 12hr ON/12hr OFF. Acrp30 and gACRP30 were prepared as previously described and labeled with ^{125}I to a specific activity of approximately 100 cpm/ng using Iodobeads (Pierce). The labeled protein was prepared immediately before injection and 0.1-0.5 μCi were injected through the tail vein. Clearance of the labeled protein from plasma was followed over 3 hrs after which the animals were perfused systemically with PBS + EDTA to remove all blood. Tissues were isolated (liver, adipose, kidney, skeletal muscle, brain), weighed, and the specific activity in plasma and tissue was determined.

Acrp30 showed a plasma half-life of about 7 hours. The plasma turnover of gAcrp30 was significantly faster showing a half-life close to 1 hour. The majority of the labeled Acrp30 protein was found in kidney and in skeletal muscle tissue, indicating that it represents a functional target tissue. A much smaller part of the injected protein was found in adipose and liver tissue and only a very small pool was seen in brain.

Immunohistochemistrey Studies

Frozen sections of skeletal muscle from mice were stained using an antibody to the globular head of Acrp30 coupled with colorimetric detection. Briefly, C57 mice were sacrificed and various skeletal muscles were isolated. Muscles were frozen in an isopentane/liquid nitrogen bath. Tissue was then sectioned at 8 microns using a Leica 3050 cryostat and sections were picked up on microscope slides. Slides were dried overnight and fixed with 4 °C acetone after which sections were pretreated for endogenous peroxidase and biotin prior to IHC. An antibody to gAcrp30 was used on the slides at a concentration of 1:20,000. The primary antibody was detected using a biotin-labeled streptavidin system. The chromagen was DAB with hematoxylin counterstain

Cross-sectional views of skeletal muscle show distinct outlining of muscle fibers with Acrp30 staining. A positive signal is also seen in any blood vessels in the tissue. This is not surprising since the animals were not perfused before tissues were isolated and Acrp30 should thus

be present in the plasma that would be in these vessels. This staining appears to be specific given that tissues stained with preimmune at the same concentration were clean. Also it should be noted that tissues without much Acrp30, such as liver, do not show much Acrp30 staining.

The substantial presence of Acrp30 in skeletal muscle supports the inventor's belief that muscle is in fact a target tissue of this molecule.

REFERENCES

Dehouck et al. J Neurochem 54:1798-801, 1990

Shapiro, and Scherer, Curr. Biol. 8:335-338, 1998

Uysal, et al. Nature 389:610-614, 1997

5

CLAIMS

1. A method of accelerating muscle cell differentiation, comprising contacting muscle cells with gOBG3 under conditions wherein said gOBG3 binds to said cells thereby accelerating differentiation of said cells.

2. The method of claim 1, wherein said cells are in an individual.

3. The method of claim 2, wherein said gOBG3 is present in a pharmaceutical composition.

4. The method of claim 3, wherein said gOBG3 is gApm1.

5. A method of accelerating muscle cell reorganization, comprising contacting muscle cells with gOBG3 under conditions wherein said gOBG3 binds to said cells thereby accelerating reorganization of said cells.

6. The method of claim 5, wherein said cells are in an individual.

7. The method of claim 6, wherein said gOBG3 is present in a pharmaceutical composition.

8. The method of claim 7, wherein said gOBG3 is gApm1.

9. A method of increasing muscle mass in an individual, comprising contacting muscle cells in said individual with gOBG3 under conditions wherein said gOBG3 binds to said cells thereby accelerating the reorganization and differentiation of said cells and increasing said muscle mass.

10. The method of claim 9, wherein said gOBG3 is present in a pharmaceutical composition.

11. The method of claim 10, wherein said gOBG3 is gApm1.

12. A method of treating muscle cell disorders in an individual, comprising contacting muscle cells in said individual with gOBG3 under conditions wherein said gOBG3 binds to said cells thereby accelerating the reorganization and differentiation of said cells, and thereby treating said muscle cell disorders.

13. The method of claim 12, wherein said muscle cell disorders are selected from the group consisting of muscle-related eye disorders, muscle-related recovery after injuries, muscle-related recovery after surgery, muscle-related disorders of aging, muscle atrophy, muscle wasting, and muscular dystrophy.

14. The method of claim 13, wherein said gOBG3 is present in a pharmaceutical composition.

15. The method of claim 14, wherein said gOBG3 is gApm1.

```
                    10                  20                  30
1     MLLLGAVLLLLALPGHDQE---TTTQGPGV      apm1protein
1     MLLLQALLFLLILPSHAEDDVTTTEELAPA      adipoQprotein
1     MLLLQALLFLLILPSHAEDDVTTTEELAPA      acrp30protein2

                    40                  50                  60
28    LLPLPKGACTGWMAGIPGHPGHNGAPGRDG      apm1protein
31    LVPPPKGTCAGWMAGIPGHSGHNGTPGRDG      adipoQprotein
31    LVPPPKGTCAGWMAGIPGHPGHNGTPGRDG      acrp30protein2

                    70                  80                  90
58    RDGTPGEKGEKGDPGLLGPKGDIGETGVPG      apm1protein
61    RDGTPGEKGEKGDSGLLGPKGETGDVGMTG      adipoQprotein
61    RDGTPGEKGEKGDAGLLGPKGETGDVGMTG      acrp30protein2

                    100                 110                 120
88    AEGPRGFPGIQGRKGEPGEGAYVYRSAFSV      apm1protein
91    AEGPRGFPGTPGRKGEPGEAAYVYRSGFSV      adipoQprotein
91    AEGPRGFPGTPGRKGEPGEAAYMYRSAFSV      acrp30protein2

                    130                 140                 150
118   GLETYVTIPNMPIRFTKIFYNQQNHYDGST      apm1protein
121   GLETRVTVPNVPIRFTKIFYNQQNHYDNST      adipoQprotein
121   GLETRVTVPNVPIRFTKIFYNQQNHYDGST      acrp30protein2

                    160                 170                 180
148   GKFHCNIPGLYYFAYHITVYMKDVKVSLFK      apm1protein
151   GKFYCNIPGLYYFSYHITVYMKDVKVSLFK      adipoQprotein
151   GKFYCNIPGLYYFSYHITVYMKDVKVSLFK      acrp30protein2

                    190                 200                 210
178   KDKAMLFTYDQYQENNVDQASGSVLLHLEV      apm1protein
181   KDKAVLFTYDQYQEKNVDQASGSVLLHLEV      adipoQprotein
181   KDKAVLFTYDQYQEKNVDQASGSVLLHLEV      acrp30protain2

                    220                 230                 240
208   GDQVWLQVYGEGERNGLYADNDNDSTFTGF      apm1protein
211   GDQVWLQVYGDGDHNGLYADNVNDSTFTGF      adipoQprotein
211   GDQVWLQVYGDGDHNGLYADNVNDSTFTGF      acrp30protein2

238   LLYHDTN.                            apm1protein
241   LLFHDT-N                            adipoQprotein
241   LLYHDT-N                            acrp30protein2
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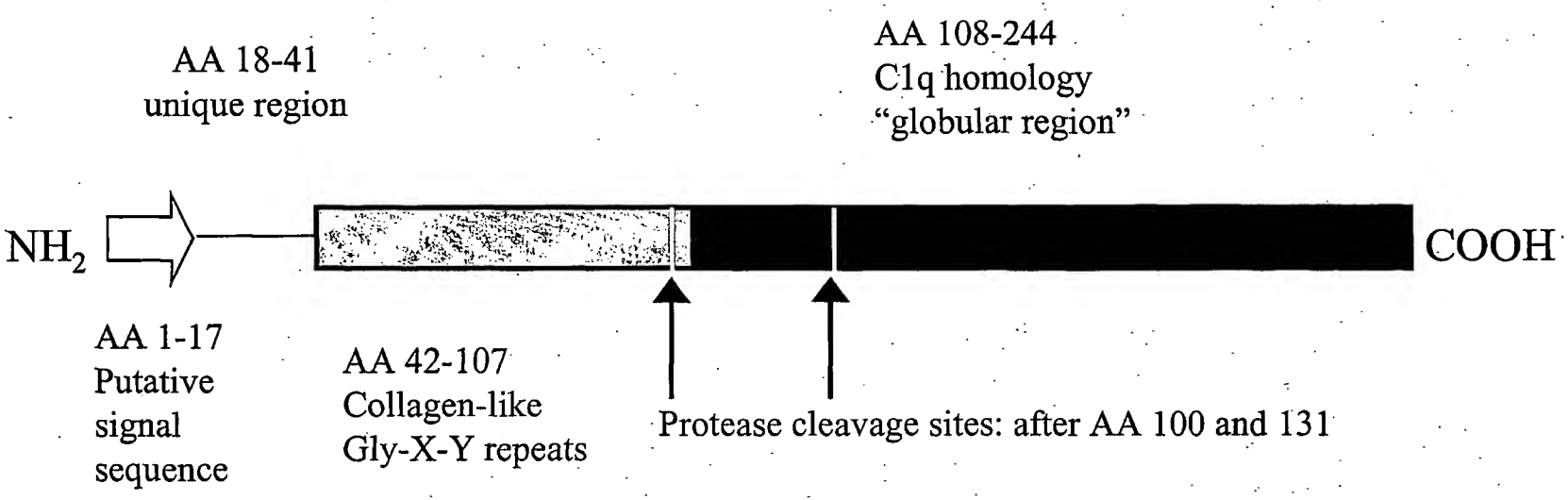
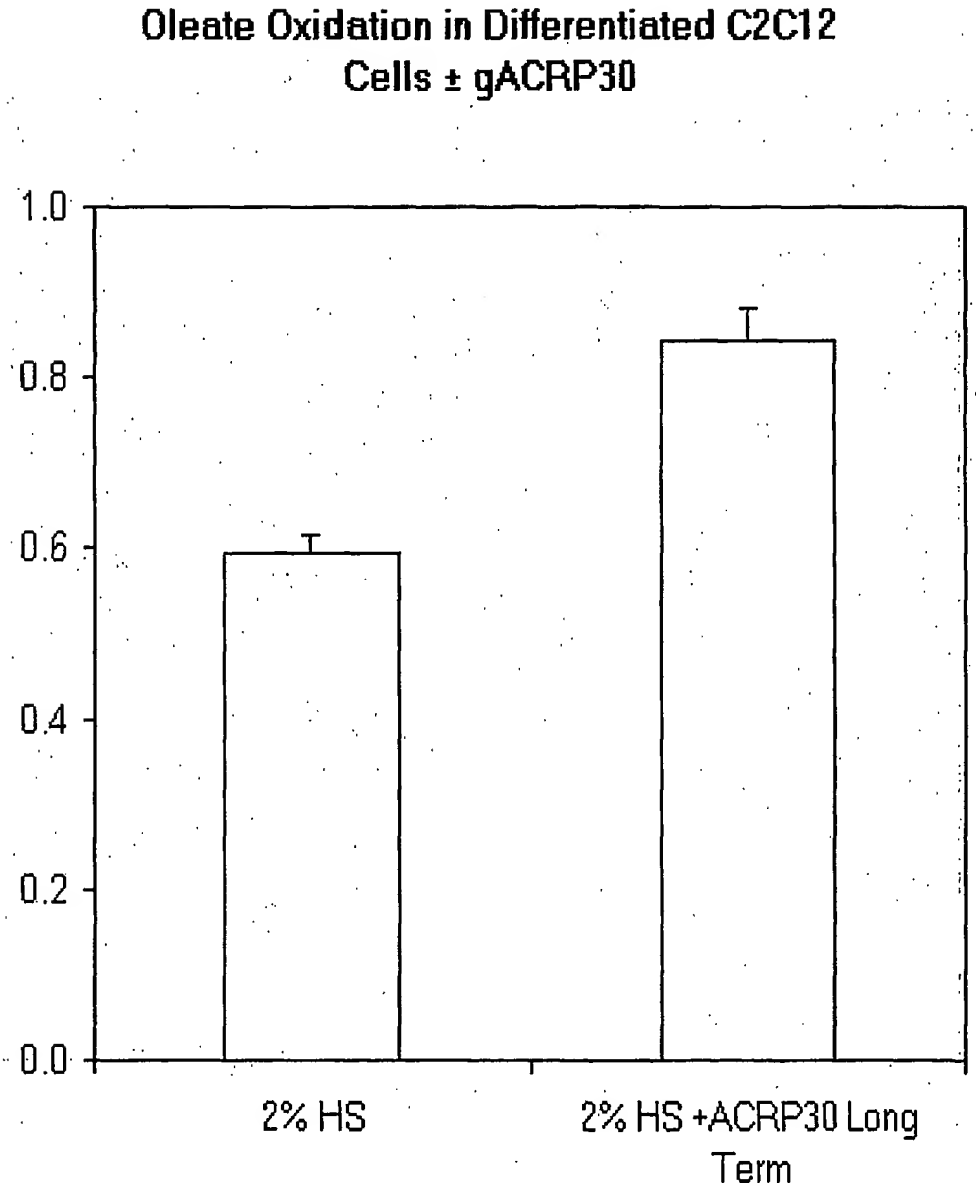
FIG. 1

Schematic drawing of Apm1 protein structure
(mouse homologue = Acrp30)



Acrp30/C1q homology overall = 26%
collagen region = 41%
globular region = 36%

FIG. 2


Oleate Oxidation in Differentiated C2C12 Cells ± gACRP30
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0.8
0.6
0.4
0.2
0.0
2% HS
2% HS +ACRP30 Long Term

Figure 3

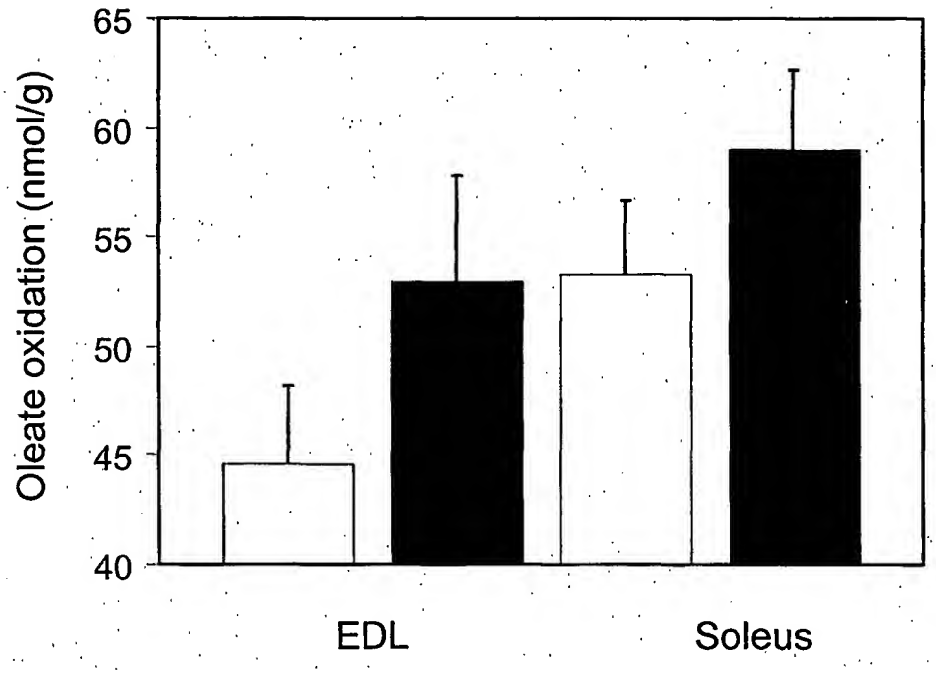
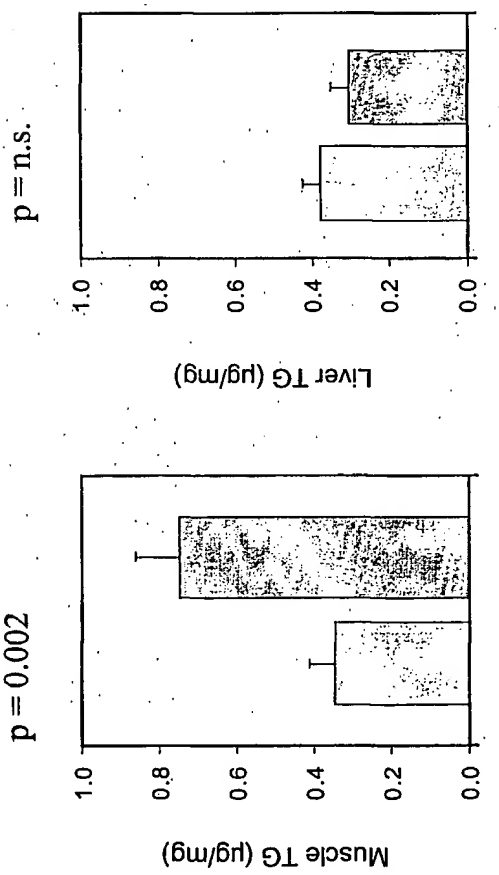


FIG. 4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Muscle TG (µg/mg)
1.0
0.8
0.6
0.4
0.2
0.0

FIG. 5A

p = n.s.
Liver TG (µg/mg)
control
gACRP30
1.0
0.8
0.6
0.4
0.2
0.0

FIG. 5B

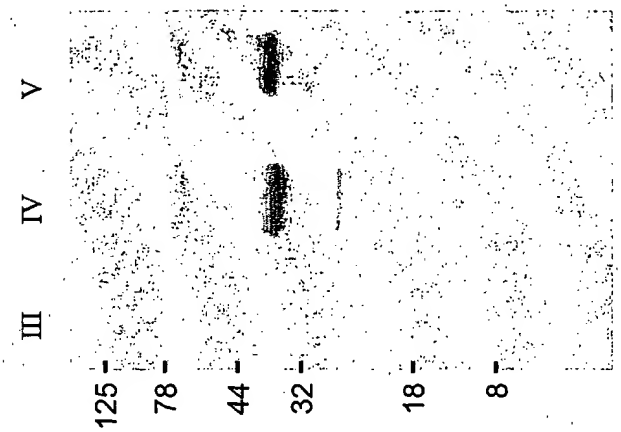

FIG. 6B

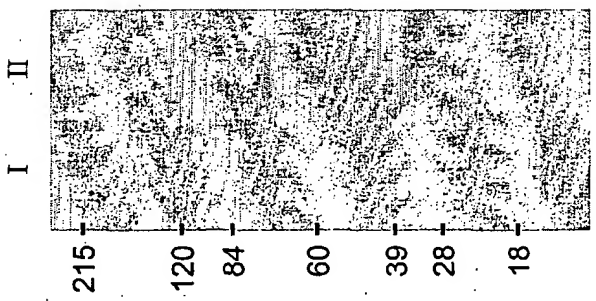

FIG.6A

Sequence Listing

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ctg ccc agt cat gcc gaa gat gac gtt act aca act gaa gag cta gct      100
Leu Pro Ser His Ala Glu Asp Asp Val Thr Thr Thr Glu Glu Leu Ala
        15                  20                  25
cct gct ttg gtc cct cca ccc aag gga act tgt gca ggt tgg atg gca      148
Pro Ala Leu Val Pro Pro Pro Lys Gly Thr Cys Ala Gly Trp Met Ala
    30                  35                  40
ggc atc cca gga cat tct ggc cac aat ggc aca cca ggc cgt gat ggc      196
Gly Ile Pro Gly His Ser Gly His Asn Gly Thr Pro Gly Arg Asp Gly
45                  50                  55                  60
aga gat ggc act cct gga gag aag gga gag aaa gga gat tca ggt ctt      244
Arg Asp Gly Thr Pro Gly Glu Lys Gly Glu Lys Gly Asp Ser Gly Leu
                65                  70                  75
ctt ggt cct aag ggt gag aca gga gat gtt gga atg aca gga gct gaa      292
Leu Gly Pro Lys Gly Glu Thr Gly Asp Val Gly Met Thr Gly Ala Glu
            80                  85                  90
ggg cct cgg ggc ttc ccc gga acc cct ggc agg aaa gga gag cct gga      340
Gly Pro Arg Gly Phe Pro Gly Thr Pro Gly Arg Lys Gly Glu Pro Gly
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gaa gcc gct tat gtg tat cgc tca ggc ttc agt gtg ggg ctg gag acc      388
Glu Ala Ala Tyr Val Tyr Arg Ser Gly Phe Ser Val Gly Leu Glu Thr
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cgc gtc act gtt ccc aat gta ccc att cgc ttt act aag atc ttc tac      436
Arg Val Thr Val Pro Asn Val Pro Ile Arg Phe Thr Lys Ile Phe Tyr
125                 130                 135                 140
aac caa cag aat cat tat gac aac agc act ggc aag ttc tac tgc aac      484
Asn Gln Gln Asn His Tyr Asp Asn Ser Thr Gly Lys Phe Tyr Cys Asn
                145                 150                 155
att ccg gga ctc tac tac ttc tct tac cac atc acg gtg tac atg aaa      532
Ile Pro Gly Leu Tyr Tyr Phe Ser Tyr His Ile Thr Val Tyr Met Lys
            160                 165                 170
gat gtg aag gtg agc ctc ttc aag aag gac aag gcc gtt ctc ttc acc      580
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Tyr Asp Gln Tyr Gln Glu Lys Asn Val Asp Gln Ala Ser Gly Ser Val
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ctc ctc cat ctg gag gtg gga gac caa gtc tgg ctc cag gtg tat ggg      676
Leu Leu His Leu Glu Val Gly Asp Gln Val Trp Leu Gln Val Tyr Gly
205                 210                 215                 220
gat ggg gac cac aat gga ctc tat gca gat aac gtc aac gac tct aca      724
Asp Gly Asp His Asn Gly Leu Tyr Ala Asp Asn Val Asn Asp Ser Thr
                225                 230                 235
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Phe Thr Gly Phe Leu Leu Phe His Asp Thr Asn  *
            240                 245
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gattgatttt attgcttagt ttgagagtcc tgagtattat ccacacgtgt actcacttgt    890
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gcttcacaat attcgcatga ctgtctggaa gtagaccatg ctatttttct gctcactgta   1070
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Pro Pro Pro Lys Gly Thr Cys Ala Gly Trp Met Ala Gly Ile Pro Gly
        35                  40                  45
His Ser Gly His Asn Gly Thr Pro Gly Arg Asp Gly Arg Asp Gly Thr
    50                  55                  60
Pro Gly Glu Lys Gly Glu Lys Gly Asp Ser Gly Leu Leu Gly Pro Lys
65                  70                  75                  80
Gly Glu Thr Gly Asp Val Gly Met Thr Gly Ala Glu Gly Pro Arg Gly
                85                  90                  95
Phe Pro Gly Thr Pro Gly Arg Lys Gly Glu Pro Gly Glu Ala Ala Tyr
            100                 105                 110
Val Tyr Arg Ser Gly Phe Ser Val Gly Leu Glu Thr Arg Val Thr Val
        115                 120                 125
Pro Asn Val Pro Ile Arg Phe Thr Lys Ile Phe Tyr Asn Gln Gln Asn
    130                 135                 140
His Tyr Asp Asn Ser Thr Gly Lys Phe Tyr Cys Asn Ile Pro Gly Leu
145                 150                 155                 160
Tyr Tyr Phe Ser Tyr His Ile Thr Val Tyr Met Lys Asp Val Lys Val
                165                 170                 175
Ser Leu Phe Lys Lys Asp Lys Ala Val Leu Phe Thr Tyr Asp Gln Tyr
            180                 185                 190
Gln Glu Lys Asn Val Asp Gln Ala Ser Gly Ser Val Leu Leu His Leu
        195                 200                 205
Glu Val Gly Asp Gln Val Trp Leu Gln Val Tyr Gly Asp Gly Asp His
    210                 215                 220
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225                 230                 235                 240
Leu Leu Phe His Asp Thr Asn
                245

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<212> DNA
<213> mus musculus

<400> 3

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Gln Ala Leu Leu Phe Leu Leu Ile Leu Pro Ser His Ala Glu Asp Asp
5                   10                  15                  20
gtt act aca act gaa gag cta gct cct gct ttg gtc cct cca ccc aag      153
Val Thr Thr Thr Glu Glu Leu Ala Pro Ala Leu Val Pro Pro Pro Lys
                25                  30                  35
gga act tgt gca ggt tgg atg gca ggc atc cca gga cat cct ggc cac      201
Gly Thr Cys Ala Gly Trp Met Ala Gly Ile Pro Gly His Pro Gly His
            40                  45                  50
aat ggc aca cca ggc cgt gat ggc aga gat ggc act cct gga gag aag      249
Asn Gly Thr Pro Gly Arg Asp Gly Arg Asp Gly Thr Pro Gly Glu Lys
        55                  60                  65
gga gag aaa gga gat gca ggt ctt ctt ggt cct aag ggt gag aca gga      297
Gly Glu Lys Gly Asp Ala Gly Leu Leu Gly Pro Lys Gly Glu Thr Gly
    70                  75                  80
gat gtt gga atg aca gga gct gaa ggg cca cgg ggc ttc ccc gga acc      345
Asp Val Gly Met Thr Gly Ala Glu Gly Pro Arg Gly Phe Pro Gly Thr
85                  90                  95                  100
cct ggc agg aaa gga gag cct gga gaa gcc gct tat atg tat cgc tca      393
Pro Gly Arg Lys Gly Glu Pro Gly Glu Ala Ala Tyr Met Tyr Arg Ser
                105                 110                 115
gcg ttc agt gtg ggg ctg gag acc cgc gtc act gtt ccc aat gta ccc      441
Ala Phe Ser Val Gly Leu Glu Thr Arg Val Thr Val Pro Asn Val Pro
            120                 125                 130
att cgc ttt act aag atc ttc tac aac caa cag aat cat tat gac ggc      489
Ile Arg Phe Thr Lys Ile Phe Tyr Asn Gln Gln Asn His Tyr Asp Gly
        135                 140                 145
agc act ggc aag ttc tac tgc aac att ccg gga ctc tac tac ttc tct      537
Ser Thr Gly Lys Phe Tyr Cys Asn Ile Pro Gly Leu Tyr Tyr Phe Ser
    150                 155                 160
tac cac atc acg gtg tac atg aaa gat gtg aag gtg agc ctc ttc aag      585
Tyr His Ile Thr Val Tyr Met Lys Asp Val Lys Val Ser Leu Phe Lys
165                 170                 175                 180
aag gac aag gcc gtt ctc ttc acc tac gac cag tat cag gaa aag aat      633
Lys Asp Lys Ala Val Leu Phe Thr Tyr Asp Gln Tyr Gln Glu Lys Asn
                185                 190                 195
gtg gac cag gcc tct ggc tct gtg ctc ctc cat ctg gag gtg gga gac      681
Val Asp Gln Ala Ser Gly Ser Val Leu Leu His Leu Glu Val Gly Asp
            200                 205                 210
caa gtc tgg ctc cag gtg tat ggg gat ggg gac cac aat gga ctc tat      729
Gln Val Trp Leu Gln Val Tyr Gly Asp Gly Asp His Asn Gly Leu Tyr
        215                 220                 225
gca gat aac gtc aac gac tct aca ttt act ggc ttt ctt ctc tac cat      777
Ala Asp Asn Val Asn Asp Ser Thr Phe Thr Gly Phe Leu Leu Tyr His
    230                 235                 240
gat acc aac tga ctgcaactac ccatagccca tacaccagga gaatcatgga          829
Asp Thr Asn  *
245
acagtcgaca cactttcagc ttagtttgag agattgattt tattgcttag tttgagagtc    889
ctgagtatta tccacacgtg tactcacttg ttcattaaac gactttataa aaaataattt    949
gtgttcctag tccagaaaaa aaggcactcc ctggtctcca cgactcttac atggtagcaa   1009
taacagaatg aaaatcacat ttggtatggg ggcttcacaa tattcgcatg actgtctgga   1069
agtagaccat gctatttttc tgctcactgt acacaaatat tgttcacata aaccctataa   1129
tgtaaatatg aaatacagtg attactcttc tcacaggctg agtgtatgaa tgtctaaaga   1189
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Pro Pro Pro Lys Gly Thr Cys Ala Gly Trp Met Ala Gly Ile Pro Gly
        35                  40                  45
His Pro Gly His Asn Gly Thr Pro Gly Arg Asp Gly Arg Asp Gly Thr
    50                  55                  60
Pro Gly Glu Lys Gly Glu Lys Gly Asp Ala Gly Leu Leu Gly Pro Lys
65                  70                  75                  80
Gly Glu Thr Gly Asp Val Gly Met Thr Gly Ala Glu Gly Pro Arg Gly
                85                  90                  95
Phe Pro Gly Thr Pro Gly Arg Lys Gly Glu Pro Gly Glu Ala Ala Tyr
            100                 105                 110
Met Tyr Arg Ser Ala Phe Ser Val Gly Leu Glu Thr Arg Val Thr Val
        115                 120                 125
Pro Asn Val Pro Ile Arg Phe Thr Lys Ile Phe Tyr Asn Gln Gln Asn
    130                 135                 140
His Tyr Asp Gly Ser Thr Gly Lys Phe Tyr Cys Asn Ile Pro Gly Leu
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Tyr Tyr Phe Ser Tyr His Ile Thr Val Tyr Met Lys Asp Val Lys Val
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Ser Leu Phe Lys Lys Asp Lys Ala Val Leu Phe Thr Tyr Asp Gln Tyr
            180                 185                 190
Gln Glu Lys Asn Val Asp Gln Ala Ser Gly Ser Val Leu Leu His Leu
        195                 200                 205
Glu Val Gly Asp Gln Val Trp Leu Gln Val Tyr Gly Asp Gly Asp His
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Asn Gly Leu Tyr Ala Asp Asn Val Asn Asp Ser Thr Phe Thr Gly Phe
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Leu Leu Tyr His Asp Thr Asn
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cta tta gct ctg ccc ggg cat gac cag gaa acc acg act caa ggg ccc      101
Leu Leu Ala Leu Pro Gly His Asp Gln Glu Thr Thr Thr Gln Gly Pro
10                  15                  20                  25
gga gtc ctg ctt ccc ctg ccc aag ggg gcc tgc aca ggt tgg atg gcg      149
Gly Val Leu Leu Pro Leu Pro Lys Gly Ala Cys Thr Gly Trp Met Ala
                30                  35                  40
ggc atc cca ggg cat ccg ggc cat aat ggg gcc cca ggc cgt gat ggc      197
Gly Ile Pro Gly His Pro Gly His Asn Gly Ala Pro Gly Arg Asp Gly
            45                  50                  55
aga gat ggc acc cct ggt gag aag ggt gag aaa gga gat cca ggt ctt      245
Arg Asp Gly Thr Pro Gly Glu Lys Gly Glu Lys Gly Asp Pro Gly Leu
        60                  65                  70
att ggt cct aag gga gac atc ggt gaa acc gga gta ccc ggg gct gaa      293
Ile Gly Pro Lys Gly Asp Ile Gly Glu Thr Gly Val Pro Gly Ala Glu
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    75                  80                  85
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90                  95                  100                 105
gaa ggt gcc tat gta tac cgc tca gca ttc agt gtg gga ttg gag act      389
Glu Gly Ala Tyr Val Tyr Arg Ser Ala Phe Ser Val Gly Leu Glu Thr
                110                 115                 120
tac gtt act atc ccc aac atg ccc att cgc ttt acc aag atc ttc tac      437
Tyr Val Thr Ile Pro Asn Met Pro Ile Arg Phe Thr Lys Ile Phe Tyr
            125                 130                 135
aat cag caa aac cac tat gat ggc tcc act ggt aaa ttc cac tgc aac      485
Asn Gln Gln Asn His Tyr Asp Gly Ser Thr Gly Lys Phe His Cys Asn
        140                 145                 150
att cct ggg ctg tac tac ttt gcc tac cac atc aca gtc tat atg aag      533
Ile Pro Gly Leu Tyr Tyr Phe Ala Tyr His Ile Thr Val Tyr Met Lys
    155                 160                 165
gat gtg aag gtc agc ctc ttc aag aag gac aag gct atg ctc ttc acc      581
Asp Val Lys Val Ser Leu Phe Lys Lys Asp Lys Ala Met Leu Phe Thr
170                 175                 180                 185
tat gat cag tac cag gaa aat aat gtg gac cag gcc tcc ggc tct gtg      629
Tyr Asp Gln Tyr Gln Glu Asn Asn Val Asp Gln Ala Ser Gly Ser Val
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ctc ctg cat ctg gag gtg ggc gac caa gtc tgg ctc cag gtg tat ggg      677
Leu Leu His Leu Glu Val Gly Asp Gln Val Trp Leu Gln Val Tyr Gly
            205                 210                 215
gaa gga gag cgt aat gga ctc tat gct gat aat gac aat gac tcc acc      725
Glu Gly Glu Arg Asn Gly Leu Tyr Ala Asp Asn Asp Asn Asp Ser Thr
        220                 225                 230
ttc aca ggc ttt ctt ctc tac cat gac acc aac tga tcaccactaa           771
Phe Thr Gly Phe Leu Leu Tyr His Asp Thr Asn  *
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Lys Gly Ala Cys Thr Gly Trp Met Ala Gly Ile Pro Gly His Pro Gly
        35                  40                  45
His Asn Gly Ala Pro Gly Arg Asp Gly Arg Asp Gly Thr Pro Gly Glu
    50                  55                  60
Lys Gly Glu Lys Gly Asp Pro Gly Leu Ile Gly Pro Lys Gly Asp Ile
65                  70                  75                  80
Gly Glu Thr Gly Val Pro Gly Ala Glu Gly Pro Arg Gly Phe Pro Gly
                85                  90                  95
Ile Gln Gly Arg Lys Gly Glu Pro Gly Glu Gly Ala Tyr Val Tyr Arg
            100                 105                 110
Ser Ala Phe Ser Val Gly Leu Glu Thr Tyr Val Thr Ile Pro Asn Met
        115                 120                 125
Pro Ile Arg Phe Thr Lys Ile Phe Tyr Asn Gln Gln Asn His Tyr Asp
    130                 135                 140
Gly Ser Thr Gly Lys Phe His Cys Asn Ile Pro Gly Leu Tyr Tyr Phe
145                 150                 155                 160
Ala Tyr His Ile Thr Val Tyr Met Lys Asp Val Lys Val Ser Leu Phe
                165                 170                 175
Lys Lys Asp Lys Ala Met Leu Phe Thr Tyr Asp Gln Tyr Gln Glu Asn
            180                 185                 190
Asn Val Asp Gln Ala Ser Gly Ser Val Leu Leu His Leu Glu Val Gly
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Asp Gln Val Trp Leu Gln Val Tyr Gly Glu Gly Glu Arg Asn Gly Leu
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Tyr Ala Asp Asn Asp Asn Asp Ser Thr Phe Thr Gly Phe Leu Leu Tyr
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His Asp Thr Asn
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catttatagt attcctgttt ttaattttag ccattctagt aggcatgtag tgatatctca 180
tggtgatttt aatttgcgtt tccgtaatgg ttaataatgc tgaacatctt tgcatgtgct 240

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